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A History Of American Building Technology

Edward Turberg

A HISTORY OF AMERICAN BUILDING TECHNOLOGY

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EDITED BY

Claudia Connelly
John Fugelso

DURHAM TECHNICAL INSTITUTE
Durham, North Carolina

Preface

There are excellent books which deal with new constructions, building technology, and the building trades. As these books are revised to focus on new work, the older forms of construction are not as well documented and are lost to the modern student of architecture and building. There are, at present, excellent books available which deal with architecture and its history, and some which deal with the history of building technology. However, much of what has been written on the history of building technology is scattered among various periodicals, small publications, and chapters in related textbooks. There is a need to collect such material and publish it as a well-rounded text. There is another need. . .a need to put back into existing textbooks material on older forms of construction. The addition to modern textbooks of older forms of construction and how to repair them would address the growing market of rehabilitation and preservation of older buildings.

The purpose of this book is to draw together some of the existing materials on the history of building technology and present them in a condensed form. The intent of the project was to produce a book which would be general in nature, easy to read, and interesting to a person having a first encounter with the history of building technology. The field of building technology is too vast for such a small project to contribute new information to the field. Our hope is that the students and others who read this book will look at its short-comings and its strengths, and be inspired to continue the study of this existing area. Also, the book suggests an organization which could be applied to the writing of a larger and more comprehensive text. The organization of the book is taken from the way a structure is built. It starts with the site and continues through foundation, framing, exterior finish, interior finish, hardware, electrical systems, mechanical systems, plumbing, coating, and regional characteristics.

The project was funded by the Mary Reynolds Babcock Foundation. Their generous support, and gracious understanding of the complex and time-consuming nature of an in-house project has carried us over many trying times. The project was conceived by John Crumpton, the President of Durham Technical Institute. He was aided in the inital stages by Randall Cain, Director of Advancement. Mr. Cain's able comments, humor, and insite were an inspiration to everyone involved. The typing of the manuscript was done by LuAnn Mullins, the type-setting by Randy Bass, and the printing by Larry Medlin and Lee Richardson. To these people we extend our sincere thanks.

Claudia Connelly
John Fugelso
Edward Turberg

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INTRODUCTION

One of the most interesting aspects of the study of old buildings is the abililty to see and recognize the clues that identify the technology of the past. These are the fingerprints of the craftsman of old, left behind in the marks of his tools. "By looking at an old house," wrote Eric Sloane, "you can imagine the maker much more clearly than you can by beholding anything made today."

Unlike our modern building technology which is aimed at a mass market and therefore tends toward uniformity, many of the buildings of the past were as different as the men who built them and the times in which they were erected. A study of the history of building technology is a glimpse into the past. It shows us the people and their ways as well as the means by which they brought about changes and improvements over time.

The history of building technology is one of the four basic ways in which preservationists study and understand old structures. Each method is important as it helps produce a three-dimensional picture of the object being analyzed.

The first of these methods is historical research, the study of written and perhaps oral records left to us by our ancestors. These records are in the form of deeds, wills, letters, journals, census reports, maps, newspaper articles, business records, patents, and a wealth of other items. By careful study of these documents the historian develops an understanding of the people and times depicted in a way that cannot be seen so clearly in any other manner. The historian can recapture the names of the first settlers of an area, why they chose that particular location, what they built and where, what their occupations were and perhaps even specific costs and materials of a structure. Thus even before the site is visited the historian can explain many facts about the area and the people who inhabited it.

The second method is archeology. This is the study of the existing remains of a culture through the relics or artifacts that have been left behind often under the ground. The archeologist is interested in written records as well as the artifacts he finds because both types of information will give added dimension to an understanding of the site. Just as historical research gives clues to the people who settled in a region, so too the archeologist can uncover the very items mentioned in the documents and verify that this site is the one in which we are interested.

The third method is architectural history. This is the study of different styles or designs used in buildings at different periods in history. What are the features of a building's appearance that put it into a recognizable period? What did the architect or builder do to make his structure express the tastes or the culture of a certain era? Architecture is rich in style, that characteristic of the art of building that transforms ideas into three-dimensional reality. We talk of Georgian, Federal, Greek Revival, Italianate, Victorian, and other

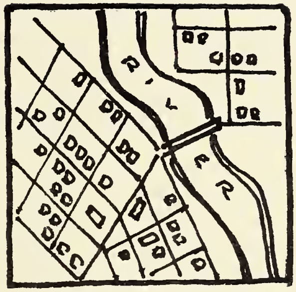
styles. By using such names we get a mental picture of specific details about the design and the fine points we expect to see in the building. We know what features came before and what features followed, both in the style and technology that was used.

The fourth method is historic building technology. This is the study of the manner in which buildings were constructed in the past and continued into our own time. The knowledge of building trades, construction methods, building materials, and the ways the builders of the past used their knowledge to produce a certain type of structure tells us a great deal about their cultural backgrounds. Where did they come from? What traditions did they bring with them? Did they accept new ideas from others in the same trades or did they stick to their old traditions? Did they develop a regional characteristic that is expressive of their own area? All these questions can be answered by a study of historic building technology combined with an understanding of the data collected through the other methods described above.

It is the purpose of this book to focus on the history of building technology and its development primarily in eastern North America at specific periods. By understanding when a particular feature of a structure was first used, when it was brought to a certain area and by whom, and when it was replaced by another technique, we get a better feeling for our heritage and begin to appreciate architecture from a new direction.

CHAPTER I: THE SITE

1980



1780

Importance of Location

In our present day we are rather limited in our selection of a place to live. We are interested in convenience, closeness to work, school, shopping, recreation, and friends, but at the same time we desire a certain amount of seclusion from the world around us. Our lives have made us increasingly dependent on the city and the town with the many services offered and less content with an isolated rural way of life.

Things were very different in the colonial era and on successive frontiers. The population of the country was much smaller, and the region between towns was taken up by farms and forests. The early settlers selected their land carefully because their future success depended on it. The character of the region into which they moved; its nearness to rivers, roads, railways; its topography; soil conditions; available raw materials; as well as the social forces of family and religion governed the choice of one tract of land over another. Thus site selection was a physical as well as cultural question since the land was the primary source of support for the family.

Relationship to Rivers, Roads, Railways, and Towns

Until well into the eighteenth century the only reliable means of transportation frequently was along the waterways of the nation. Both settlement patterns and trade routes were established on the sounds and rivers. The narrow Indian trails into the forests were dangerous during most seasons, and one was forced to go on foot along these paths at a slow and ever-watchful pace. It was difficult to ride horseback through the dense growth and almost impossible to pull a wagon through it. The cumbersome carts and laboring ox-teams were no match for the wilderness. The most practical way to go inland was to travel upstream along the rivers. As late as the mid-

nineteenth century travel by water was easier than other methods as often expressed by weary travelers in the pages of their journals.

People having land along the water routes were fortunate in their choice because they could travel and trade with relative ease. Those who had settled in the interior were isolated and had to be self-sufficient. It took the development of the steam locomotive and iron rails to conquer the land—almost two and a quarter centuries after the first ship arrived at Jamestown, Virginia.

Topography

Many early settlements were established close to the shoreline in lowlands and swamps that were breeding grounds of disease. It did not take settlers long to realize that well-drained higher ground gave good farmland and safety from mosquitos and natural calamities. Surveying parties were sent out to chart the physical features of the region and to determine the best places to build, farm, and set up industry. The surveyors were important because, by recording the conditions of the land, the new settlers could better select tracts that suited their needs.

Soil Conditions

The duties of the surveyor included evaluating soil conditions in the regions he investigated. Since virtually all the new territory was unknown and it was important to know what kinds of crops could be raised in these soils beforehand, maps had to be drawn with a variety of notations such as ground conditions (hilly or flat), soil (clay, sand, loam), open fields or forests, swampy lowlands, and many other features that would be important for the investor to know before selecting a particular piece of land.

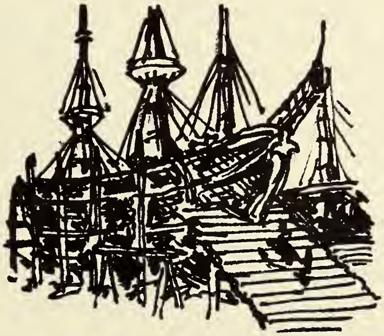
Raw Materials for Construction

In order to assure that permanent settlements could be built, the region had to be investigated for its raw materials. Topography and the mineral content of the land played a role in the building technology that could be used since the builders might have to adjust their ways of building to accommode the materials available to them. If lime

for mortar was not there mud, clay, or dry-laid masonry had to be used. The species of wood determined the size and length of framing members that could be used. This governed the size of rooms and the height of buildings. Water power was useful for mill operations, and field and river stones were valuable natural materials with which to build.

Use of the Land

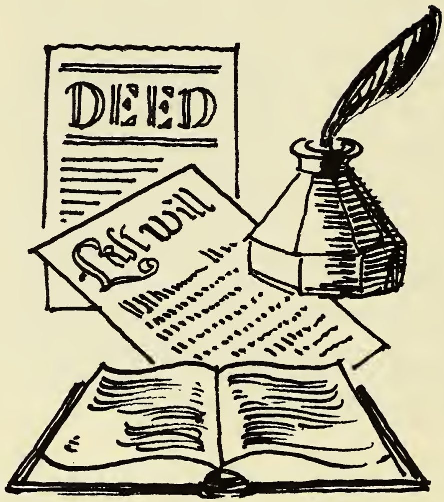
Most of the lands that were settled were used for agriculture, but in regions with sheltered harbors and rapidly flowing rivers shipbuilding and sawmilling became important trades. Once again, the evaluation of each location for its ability to support trade, agricultural or industrial, depended upon its relationship to trade routes, topography, soil conditions, and raw materials. Areas in the Northeast became principally trade centers oriented to European markets. Ships were built on the New England coast, and manufactories grew up along the rivers. In the Middle Atlantic regions and the South, farms produced tobacco, food staples, and naval stores (tar, pitch, and turpentine) as well as lumber and bricks.



SHIPBUILDING

Written Records as Back-up Information

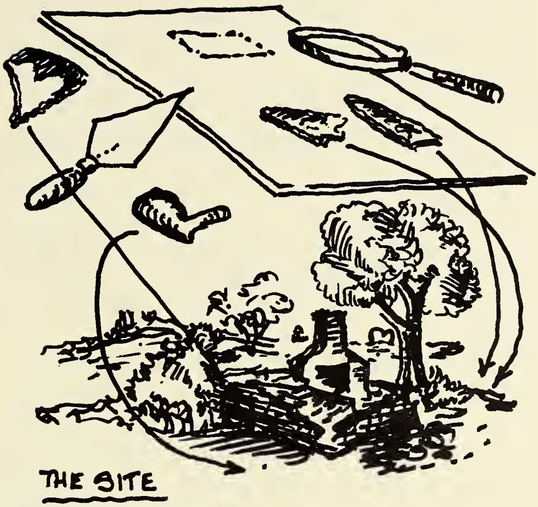
The deeds, patents, business records, wills, journals, and newspaper articles that were written and preserved give an incredible amount of information about activities in the settlements, both rural and urban. The bulk of research material found in public and private archives has filled many gaps that could not be known except for the written documents surviving from the past.



These have provided necessary information where physical evidence has disappeared. Documents also bring out the personalities of individuals from the past. When these people came to the New World they did not abandon the ways of their homeland. They brought their religion, culture, and style of living with them, expanded by ideas picked up from others who also were beginning new lives in an unfamiliar land. How they managed to use their Old World technologies and adapt to new ways is often vividly recorded in the written documents of the period.

Archeology

Investigation of a particular site begins with the written records relating to the area. The next step is to examine the physical site. Visible remains on

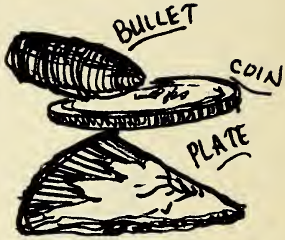


the site may provide information that might have been missed, was unclear, or was lacking from the records. The term "visible remains" has an important distinction and means that the investigator should limit himself to looking at those things that stand on or above the ground. Anything that is in the ground or below its surface is the realm of the archeologist. This rule should be respected at all times.

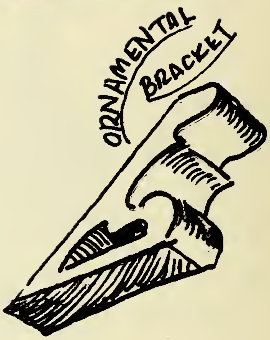
It may seem odd that scraps of china, pieces of metal, or halfburied bricks can be considered to be more important where they lie unmolested in a field than as objects displayed as evidence of the occupation of the site. But this is how the professional views these remains. To an archeologist trained to study and interpret these artifacts, the very places where the objects were dropped, buried, or placed in the corner of a field are basic to understanding the objects themselves. These objects may relate to the history of the site during the period in which we are interested (building materials, pottery, post holes), or they may relate to a time long before European settlement (arrowheads, flint tools, stone pots, campfires). The archeologist is concerned with recording the entire history of the area, not just that period of time indicated by the written records.

The distance that the artifacts are found from the location of a known structure, a distinct feature, or a contour of the land; the depth at

which the objects are found; and how they relate to the established or uncertain past is lost information if the artifacts are carelessly collected as souvenirs. An artifact that has been picked up casually from the spot where it has remained undisturbed for a century or more leaves behind a part of its history that can never be reclaimed. A Civil War bullet, an old coin, or the carved ornament from a building retains its physical worth and may even command a monetary value, but where is its full historical significance after it has been framed on the wall if the place where it was found is forgotten?



Archeology is one of the few disciplines that must destroy the site as it searches for information about the site. The archeologist therefore has developed a system of recording his data in careful detail as it is revealed to him. The material is then cataloged along with the maps and photographs which he has made. All this information can be used again and again for future reference.



Observation of Structural Remains

The structural remains of buildings on the site are the realm of the architectural historian and the historical architect. And, like archeology, a system by which data is collected and evaluated is basic to understanding the site. A step-by-step analysis of the buildings on the property is important because each piece of evidence relates to the entire study in a continuous chain of facts. The structures, whether they stand complete or only in part, are documentary evidence containing information about building technology at one particular time or over a long span of time. They tell us how the builder took the technology at his command and built something that expressed himself and his culture in three dimensions. As Winston Churchill once remarked, "We shape our dwellings, and afterwards our dwellings shape us." The process of shaping the natural environment is a part of our cultural evolution based on building technology.

CHAPTER II: FOUNDATIONS AND MATERIALS

Excavation for the Foundation

The information of a structure is more than the physical support beneath a building. It is a clue to the period in which a builder set about the task of creating a way of life for himself and for others. A close examination of the foundation can tell a lot about the background training of the builder and about the traditions that guided him in his trade. His own ability to convert materials existing around him into a useful structure that reflects the location of the site, the climate of the area, and the resources available to him are all shown by the result of his craftsmanship.

The Egyptians and Greeks built buildings that did not have foundations designed for specific loads and soils. It was the Roman engineers who solved the problems of building on unstable soils. There is a great difference between buildings or structures with engineered foundations and those built according to traditional methods. Until the last half of the eighteenth century and first half of the nineteenth century the designers of monumental buildings and structures such as bridges learned work by apprenticeship and experimentation. In the eighteenth century the profession of civil engineering began to emerge. This involved the study of sites and soils as well as the building of large projects designed to regulate nature. Engineers' skills were applied to many projects and eventually to residential buildings. This section will only take a brief look at residential foundations.

The foundation excavation, or lack of an excavation, can also provide clues to the history of a building. In many of the early houses in the colonies the foundation of a structure was little more than a cleared space on the ground over which was constructed a shelter. Trees were cut from the nearby forest, stripped of their bark, and set into post holes dug around the clearing. The floor was

the earth itself unless the owner was wealthy enough to have a brick floor installed.

Cellars were excavated in few of the early dwellings of New England and those which had them provided storage rooms for food during the cold winters. In addition the cellars acted as barriers between the ground and the principal floor. In the South storage facilities were put in small outbuildings or dependencies near the main house but often not connected with it. Again, the location of the site and the climate of the region guided the builders in the manner in which they designed their dwellings.

Types of Foundations

The foundations of some of the first permanent houses were made from squared-off timbers, cut with an axe and an adze, generally of oak, and laid on the ground according to the shape the building was to be. The vertical wall studs were fitted into pockets or mortices in the foundations, called sills (or in the English manner, cills). In low-lying areas where dampness and cold made the ground-level house uncomfortable, the sills were raised about a foot above ground and rested on short posts or on boulders.

Later, when bricks were made on the site, solid masonry foundation walls were built that resisted dampness and infestation from termites. Many of the brick foundation walls did not provide for circulation of air beneath the house, and the wood could not "breathe." This caused the joists and floors to stay damp and to deteriorate. By the beginning of the eighteenth century builders had solved this problem by installing small vents in the foundation walls, allowing air to circulate and dry out the space beneath the floors.

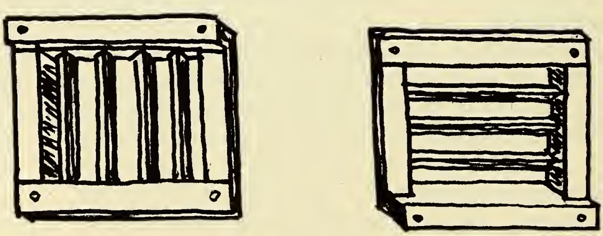
Stud: One of the smaller uprights in a building to which sheathing, paneling or laths are fastened.

Mortise: A hole cut in a piece of wood into which another piece fits to form a joint.

Sill: A heavy cross piece of wood or stone that forms the bottom member of a window or doorway. Also, a horizontal supporting piece at the base of a structure.

Joist: Small timbers or metal beams ranged parallel from wall to wall in a building to support the floor or ceiling.

FOUNDATION VENTS



Houses with cellars had larger openings in the walls that were fitted with small windows or grilles. The windows could be opened or closed according to the weather and protected the contents from intruders. The grilles had vertical or horizontal bars morticed into the frames. If the room was to be closed up, shutters were hinged to the interior frames and secured from the inside. Stairs or ladders to the cellars were built under trapdoors in the floor above, beneath the main staircase, or in exterior bulkheads.

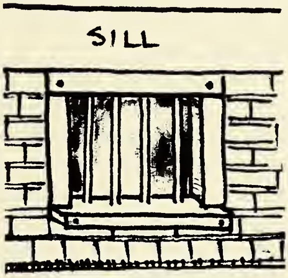
A method of constructing floor supports for houses without cellars was to set the sill on brick or stone piers. This eliminated the need to construct a continuous foundation wall, allowed air to circulate freely beneath the structure, and saved materials and labor. The spaces between the piers could be left open or could be latticework to keep small animals and debris from beneath the house. This type of treatment has continued to be used to the present day.

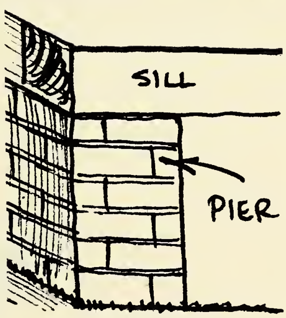
Concrete was being used in England by the 1830s. There are reports of concrete block being made in New York in the same decade. By the end of the nineteenth century concrete, concrete block, and reinforced concrete were widely used for foundation piers. Until about 1904 cement blocks were made on the site in molds along with lintels and sills for windows and doors. The development of blockmaking machines during the period after World War I brought more widespread popularity to the material and general acceptance of this method of construction. By the 1920s it had become part of the technology of building.

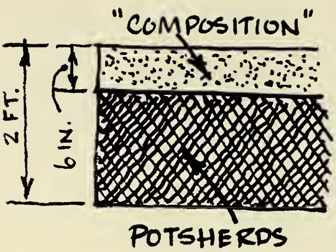
The reinforced concrete slab eliminated the cellar and traditional foundation completely and traces its beginning back to the ancient world. Slab foundations were used in "winter rooms" by the Greeks. They were". . . excavated about two feet and a foundation of potsherd [is] well rammed in. . . A composition of pounded coal lime, sand, ashes is mixed up and spread thereover, half a foot in thickness, perfectly smooth and level." This method of constructing a unit foundation and floor was not further developed until the modern architect, Frank Lloyd Wright, reintroduced it in

Bulkhead: A structure built to cover a descending stairway.

Lintel: A horizontal piece across the top of an opening that carries the weight of the structure above it.



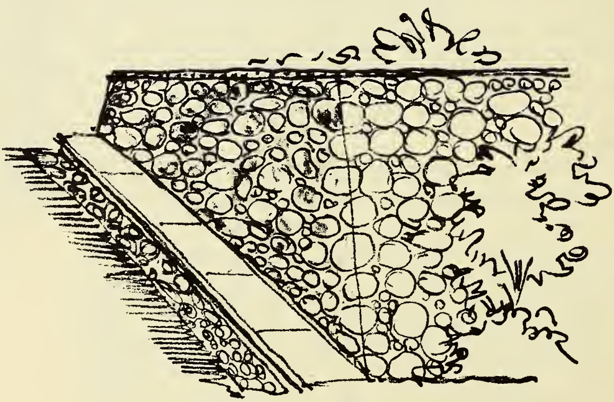




ANCIENT GREEK FLOOR

his Prairie Style houses in the Midwest. The slabs were poured over a gravel bed about sixteen inches thick, providing drainage under the house and spreading the weight of the structure in a way that is similar to ballast beneath the ties of the railroad track.

One of the most popular materials forconstructing foundations in the early colonies was stone. It was readily available in most areas of the country, especially in the uphill and inland regions. On the coast, where small river and field stones were found, brick and stone walls were constructed. And further north, where the shores were lined with massive boulders, foundations appeared to be a part of the shore itself.



BALLAST STONE WALL

One source of stones came not from local pickings but from abroad. The ballast stone which is often pointed out to visitors in coastal towns was used to stabilize ships trading between ports on either side of the Atlantic Ocean. The small, round, wave-washed stones were picked up on the beaches of British ports such as Plymouth, Portsmouth, and Southhampton and packed deep in the ships' holds to steady the ships on the high seas. Ballast stones were used for foundations in limited instances where it was easy to collect them. Perhaps they were loaded in small boats at low tide and floated to a building site on shore at high tide.

Kiln: A heated enclosure for processing a substance by burning, firing or drying.

Brick

The oldest and most popular manufactured material for construction has always been brick. The earliest surviving houses and public buildings in Egypt and the Middle East were built with sun-baked brick, as were the pueblos in the American Southwest. The process of sun-baking brick has evolved over a long period of time in almost every civilization on earth to a system of kiln-fired brick. Its ease of manufacture and the strength of the final product, added to its fine artistic effect, have justified this long popularity.

Brick manufacture went through a decline in the era between the fall of Rome and the Middle Ages, although brick building actually continued to be used in the northern lowland countries of Europe throughout this period. These builders influenced the resurgence of brick manufacture in England. In the 1300s the technique spread rapidly across Europe.Thomas Derry, in his **Short History of Technology,** stated that

> Three to four unskilled men were able to do all the work of digging and kneading the clay, shaping the bricks, and tending the kiln, for an annual output of about 100,000 bricks. It took ten to fifteen days of firing with dried turf as fuel.

By the middle of the 1600s colonial brick makers had made strides in Virginia and New England. The first brick kiln was set up in Jamestown, Virginia, in 1612, followed by one in the Dutch settlement of Manhattan in 1628, and in Salem,

Massachusetts, in 1629.

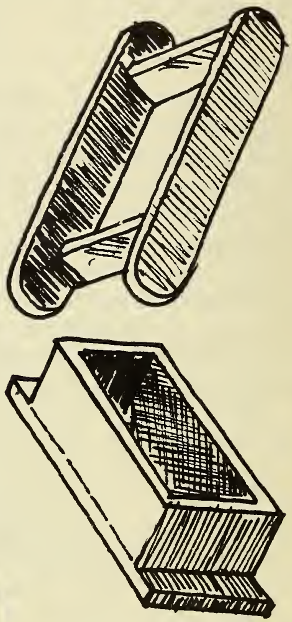
Early brick kilns or manufacturers of brick produced bricks of different sizes. Thus the colonial assemblies enacted rules for standardization. The Massachusetts legislature met in 1667 to decide on the size and method of manufacture of bricks. In 1683 the general assembly by New Jersey ruled that the approved standard brick should measure 9 1/2" x 4 1/2" x 2 3/4" (compared with our present-day standard of 8" x 3 3/4" x 2 1/4"). William Penn urged builders in Philadelphia to use brick wherever possible, and the general court of Boston stipulated that "all new buildings more than 8 feet long and 7 feet high [were] to be brick or stone and covered with slate or tile." This was an attempt to lessen the danger of fire in populated areas.

Until the middle of the 1800s bricks were molded by hand. Hand-operated brick presses were in use in the early 1800s; the clay mixture was kneaded and pressed into wooden forms, or molds, and dried. Bricks were then removed from the molds and stacked in kilns, or clamps, where they were fired to the desired hardness. Clay was available in most of the colonial settlements (despite the old tales of bricks being shipped to America as ballast), and the forests provided select woods for firing.

The temperature of the kilns had a direct effect on the quality, strength, and color of the brick. It was a learned science, dating from the Middle Ages, in which control of the heat in the kiln produced wide variations in the finished product. If

Clamp: A stack of unburnt bricks made ready for firing.

TWO TYPES OF BRICK MOLDS

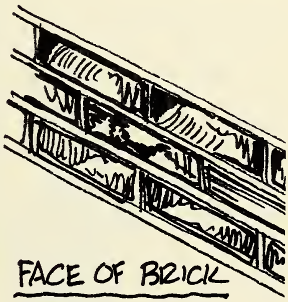


BRICKS STACKED TO FORM A KILN OR CLAMP

the fire burned at a temperature of about 1600°F, the brick became the familiar "brick-red" color. By raising the temperature to about 1800°F, the brick became reddish brown. And at 2200°F, it turned gray. In addition to temperature, the type of clay, shale, sand, moisture, iron content, and location of brick in the kiln had a direct relation to the way the finished brick turned out.

In a general way the variation in color from a pink salmon to dark brown or gray is a clue to the hardness and strength of the material. The darker the brick the stronger it is, and the greater its structural value. Clinkers, however, were bricks that were fired so hard that they became brittle and cracked easily. These were used as fill and were (and are still) considered to be of little use. Despite this clinkers were widely used in wall and foundation construction and were concealed by the finer face brick. At the other end of the range, if one sees a foundation or wall that has deteriorated to the extent that some of the bricks have spalled or sifted away, leaving only the masonry joints intact, they were probably soft-fired and put into the structure by mistake or in ignorance. The effects of dampness and applied loads greater than they could support caused this deterioration.

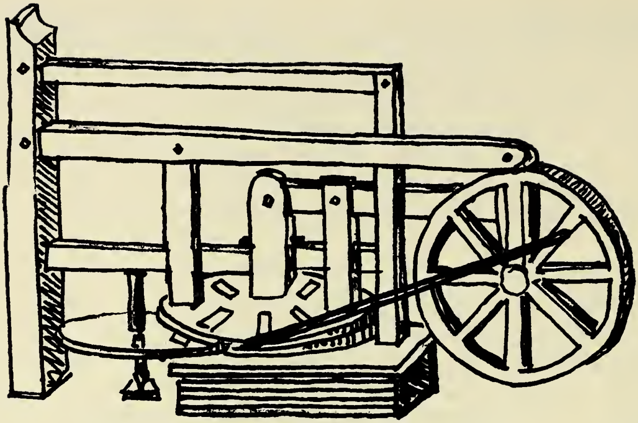
Spall: To break up, chip, split or crumble.



FACE OF BRICK BREAKING OFF OR SPALLING

George Hadfield received the first patent in the United States for a brickmaking machine in 1800. Two years later a patent was given for a repressing machine. In 1819 a brick molding machine was in operation in Washington, D.C., operating by horse power and producing 30,000 bricks over a twelve-hour period. A similar machine was used in New York in 1829 and turned out over 25,000 bricks in the same amount of time. According to one contemporary report, these "sold readily at five dollars to eight dollars per thousand." However, the industrialization of making bricks was not complete until late in the nineteenth century. The older methods of making brick survived away from urban areas.

As the demand for materials increased during the first quarter of the nineteenth century, more refinements in manufacture were developed. In 1835 a patent was issued to Nathan Sawyer for a



BRICKMAKING MACHINE, 1820

brick molding and processing machine that used "dry clay." This clay contained the same amount of moisture that it held in its natural state but required that the machine apply greater compression to the mixture to bind it together during the molding process. The result was a brick that was about eight ounces heavier and stronger than the standard brick of the day.

For the next seventy-five years further refinements continued in both the way bricks were molded and the fuels that were used. Through the period of the Civil War men experimented with tempered clay or stiff mud that was fed continuously from mold to kiln. A catalog, published in 1867 by the inventors of this process, Chambers, Brother and Company of Philadelphia, illustrated the procedure. As Harley McKee, in his monograph on masonry, has written, ". . . this was mechanization of one more stage in the brickmaking process: a step toward the modern continuous kiln."

The structure of kiln and fuels to fire them also changed with the development of brickmaking technology. By the 1830s and 1840s coal was used; today the major fuels are gas and oil.

Concrete

Previous mention has been made of the introduction of concrete in the building trades. This material has probably brought about more

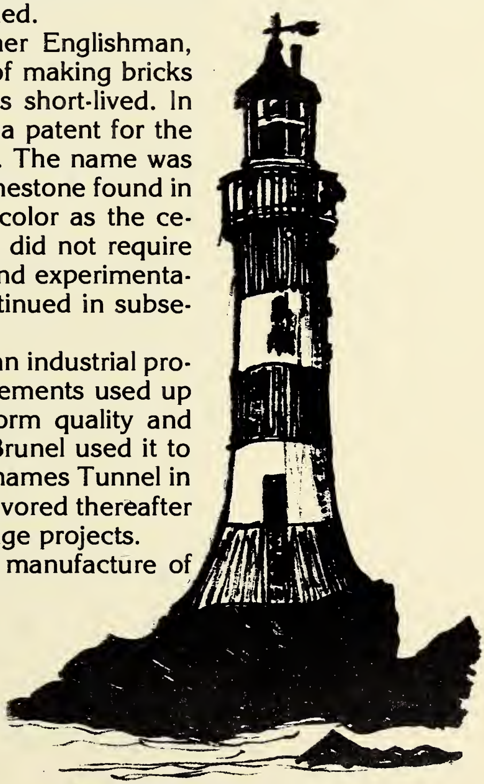
changes in the manner of constructing large and small structures than any other save steel and has dramatically influenced concepts of design.

The invention of concrete dates to the Romans, who used sandy, volcanic ash called **possolana** for the construction of roads and buildings as early as 500 B.C. In the Middle Ages cements were made by combining limestone and gypsum. Hydraulic lime, used also from antiquity, was able to harden under water because of the low content of clay in the mixture (about 20 percent). It was used with great success and dramatic publicity by John Smeaton for the foundations of the Eddystone Light off the coast of Plymouth, England, in 1756. This structure was the third lighthouse on the site, previous ones being washed away in storms and swept away by fire. Smeaton's structure was razed only after it was decided in 1877 that a larger lighthouse was needed.

In 1810 Edgar Dobbs, another Englishman, received a patent for a method of making bricks with cement, but its success was short-lived. In 1824 Joseph Aspdin was given a patent for the manufacture of Portland cement. The name was derived from Portland stone, a limestone found in the region which had the same color as the cement. Its manufacture, however, did not require the use of that particular stone and experimentation with various limestones continued in subsequent years.

Portland cement, the result of an industrial process, surpassed other forms of cements used up to that time because of its uniform quality and greater strength. In 1828, M.I. Brunel used it to fill in the river bed beneath the Thames Tunnel in London, and it continued to be favored thereafter in the majority of tunnel and bridge projects.

In America the discovery and manufacture of



EDDYSTONE LIGHT

waterproof cements came as a result of canal building. Natural cements were waterproof because of the minerals and clay they contained. They were used where the ability to harden under water was required.

The first Portland cement was not produced on a steady basis until 1875 when the Coplay Cement Company of Siegfried, Pennsylvania, changed from the manufacture of natural cements to the Portland variety.

Nevertheless Portland cement has not replaced lime cements in the building of masonry walls. Again, there is a continuity in the function and use of a material.

CHAPTER III: FRAMING

Walls

In the European tradition in North America the earliest structural frames were no more than trees cut from the forest and set into postholes in the ground. The importation of craftsmen with proper tools made it possible to cut and fit building materials in a precise fashion, saving timber and using it to better effect.

Examples of early houses have been reconstructed, based on archeological evidence, near Salem and Plymouth, Massachusetts; Jamestown, Virginia; and at Carter's Grove and Williamsburg, up-river from Jamestown. They were enclosed with fenced yards and included fortress-like structures for protection against attack.

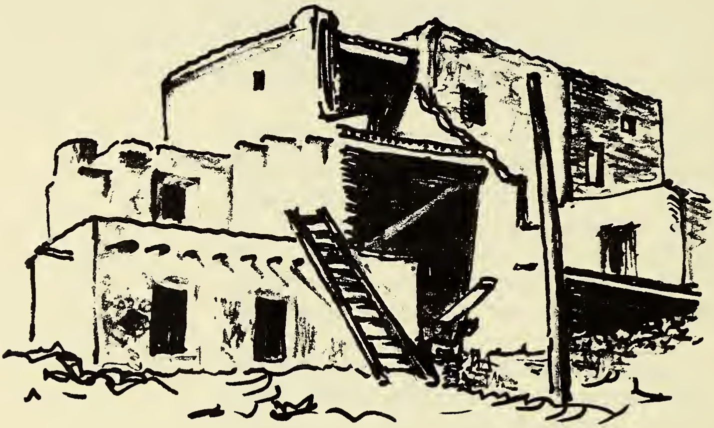
As permanent settlements began to grow, the settlers sent abroad for specialists trained in the building arts. James Marston Fitch has written that the colonists

> . . . were not long content with lean-to, sod hut, and hill-side dugout. Before the first years were out, they were ordering not mere man-power but specific types of skilled craftsmen —masons, carpenters, sawyers. They were sending detailed lists of the tools required and allowing each immigrant family a set of carpenter's tools for their home in the New World.

The tradesmen brought with them the knowledge of how a building should be put together from digging the foundation to topping the structure with a roof. The colonies were generally richer than the homeland in natural resources for construction, and the forests abounded with both familiar and unusual woods. Stones in fields, along riverbeds, and in quarries were available in some areas of the country, and clay was to be found beneath the surface for use in the manufacture of bricks.

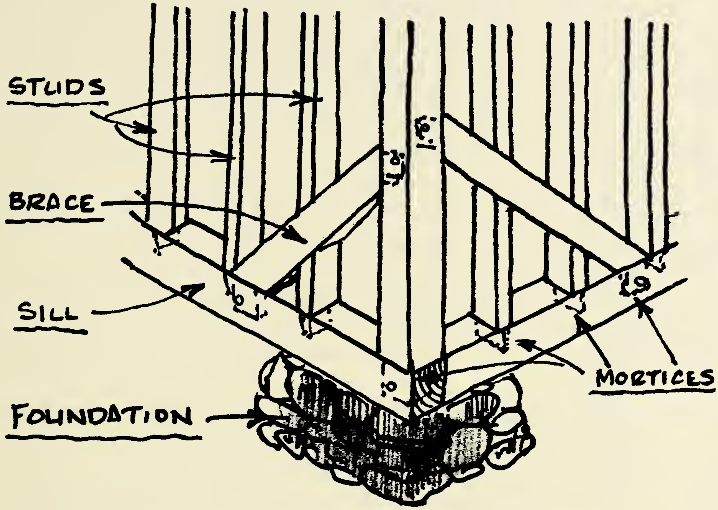
In the North most houses were built of wood but

in the Spanish Southwest the major material was adobe (sundried mud bricks). In the South as in the larger cities brick was commonly used, in the first instance because of its availability and in the second because of fire regulations. The reason for using different materials depended upon location, function of the material, and public health and safety.

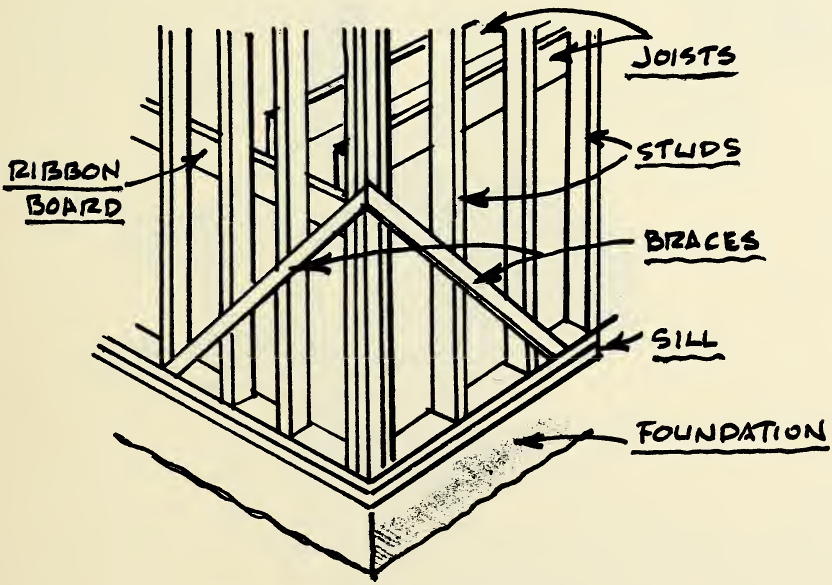


The most long-lived system of building a wall was that inherited from Medieval carpenters who framed their structures with heavy timbers, usually oak, filling the spaces between the timbers with clay, brick, or stone. An interesting feature of these buildings, still surviving in old towns of Northern Europe, is that the entire framing system can be seen from the exterior, unless the walls have been covered in later years with shingles or weatherboards.

The braced frame continued to be used in America until the Civil War when it was generally supplanted by systems based on mass production. The first great innovation in mass producing parts for buildings, other than brick, was in 1833 when Augustine Taylor, a Chicago builder, was hired to construct a small church at moderate cost. Although some credit George Washington Snow with the idea, the result is uncontested. Instead of using heavy timbers in the framework, the builder cut his materials into thinner, lighter



THE BRACED FRAME
(1600's – 1800's)



THE BALLOON FRAME (1830's)

sections than commonly found. Rather than morticing and pegging the frame together, nails and spikes were driven into the joints. The church was completed in less time than it would have been by conventional methods, and the final cost of the project was well within the means of its sponsors. One authority said of the new technique:

> A man and a boy can now attain the same results, with ease, that twenty men could on an old-fashioned frame. . . The principle of the Balloon Framing is the true one for strength, as well as for economy. If a mechanic is employed, the Balloon Frame can be put up **for forty per cent less money** than the mortice and tenon frame.

The development of this new method of construction could not have been accomplished without factorymade nails and lumber. The light construction of St. Mary's Church in Chicago was

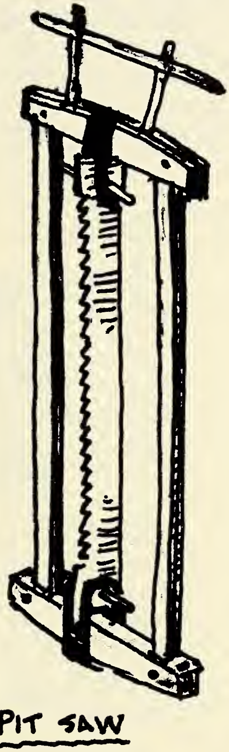
ST. MARY'S CHURCH
CHICAGO, 1833

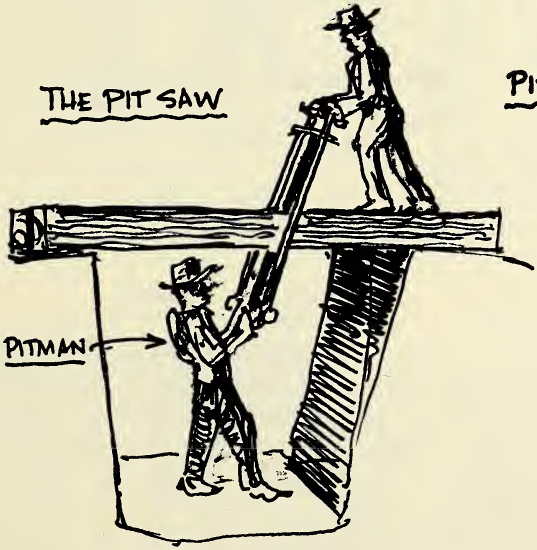
a triumph in its day and led the way for mass-produced housing in the future. Disassembled houses were sent to all parts of the country and as far abroad as Hawaii. The New York **Tribune** stated in 1855 that "if it had not been for the knowledge of the balloon-frame, Chicago and San

Francisco could never have arisen, as they did, from little villages to great cities in a single year."

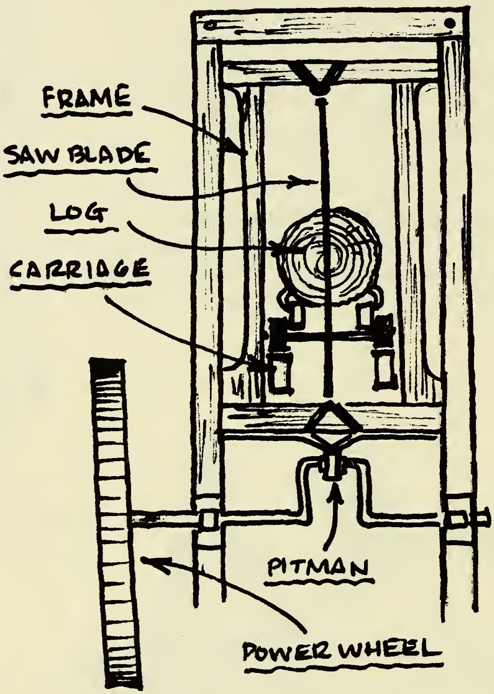
Without the aid of sawmills the early colonists had to cut their lumber by hand using long, two-man saws. The method of cutting the material was for one man to stand on top of the timber or log while the other stood below it in a pit. Thus appeared the term "pit man" which has continued in the vocabulary of the sawyer to modern days. If the log was placed on a sawhorse, with a man above and one below, the man on the ground was called the pit man. In mechanized sawmills the lower arm that controls the downward movement of the saw likewise is called the pit man.

By alternating the direction of the saw up and down the log was eventually cut to be desired size. The pattern left on the edge of the board was either a series of vertical lines across the grain or slightly angled because the sawyer above pulled the blade further in the direction of the cut than his partner.





With the development of wind and water powered saws and the invention of the steam operated saw the process of cutting lumber quickened. The long, straight saw was fitted into moving mechanical arms, the logs were fed into the blade, and the cut timber emerged from the opposite side with uniform, narrowly-spaced cuts perpendicular to the length of the boards.

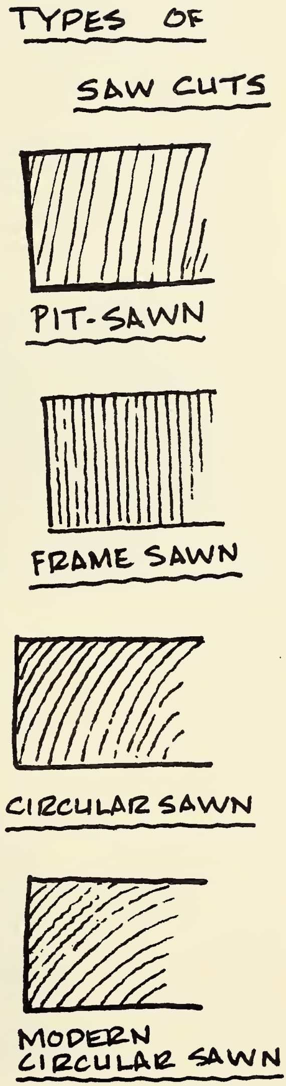


FRAME SAW

A third development in saw technology was the invention of a circular disc with teeth along its circumference. There is some evidence that this type of saw was invented as early as the 1500s or 1600s in Holland, and a Dutch patent was issued in 1644 for such a system. But the description of the mechanism is not clear and all other indication of it has disappeared. The circular saw that we know today had its origin in New England about 1790. It was in use in America by the first quarter of the nineteenth century and was probably used

to cut the framing for the previously mentioned little church in Chicago in 1833. The cut marks on boards passing through a circular saw are segmental and, by the curve, give an indication of the diameter of the blade. The more curved the cut, the smaller the blade; the straighter the curve, the larger the blade.

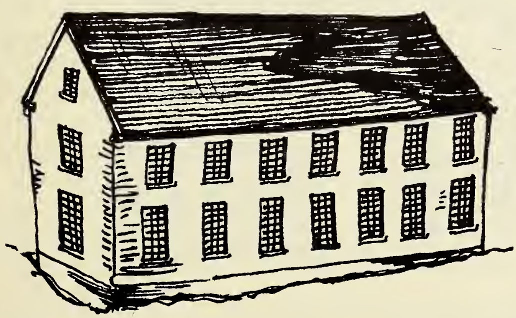
Because the blade had to be thick to give it strength, there was more waste of materials in circular saw cutting. By the early part of the twentieth century many sawmills had installed horizontal band saws which were able to trim the boards more economically because of the extreme thinness of their blades.



Metal Framing

Factories and other commercial buildings had different needs than homes. They needed more open floor space and more natural light. These requirements were first met by heavy timber construction of the medieval type and masonry construction techniques which had been developed since the Romans. However, the expansion of industry pushed old construction methods to the limits of their abilities. The need for larger, safer commercial buildings led to the use of metal. Of course, other factors such as the development of the steel industry, professional engineers, and scientific understanding of materials contributed to the rise of metal framing.

But what of the factories themselves? The large factories and mills in New England, with many-windowed walls to let in natural light, required stout framing and fireproof construction. Until



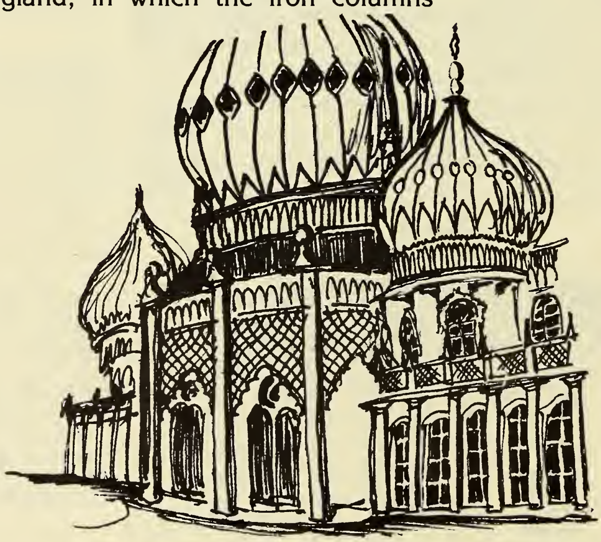
new technology arrived, these mills were constructed according to the heavy timber framing system developed from Medieval methods.

One of the steps in realizing the need to build for strength, fire safety, and economy was the introduction of cast iron into the building trades. With this structural device came a new practitioner in building technology, the engineer. Sigfried Giedion has commented that

> The cast-iron column was the first structural material produced by the new industrial methods to be used in building. As early as 1780—even before the introduction of steam power—such columns replaced wooden posts as roof supports in the first English cotton mills.

The use of iron to support large spaces had been tried in France in 1786 by Victor Louis. His Theatre Francais in Paris was constructed with roof supports of wrought iron, a material stronger than cast iron but more expensive to produce. This was followed in 1801 by a mill in Salford, England, by Watt and Bolton with both columns and beams made from iron.

In 1818, John Nash designed a picturesque pleasure pavilion for the Prince of Wales at Brighton, England, in which the iron columns

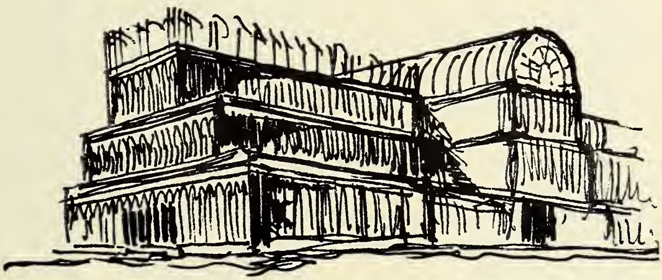


BRIGHTON PAVILION

were formed into fantastic Egyptian and palm-leaf motifs to disguise their long and slender forms.

The Galerie d'Orleans in Paris was the initial structure to contain an iron-and-glass roof spanning an arcade. Built in 1829, the structure became a model for exposition buildings, stores, and railway stations for the next century. The most famous of these glass buildings—virtually a series of interconnecting glass boxes—was the Crystal Palace Exposition building designed in 1851 by Joseph Paxton. It was built just outside London and received such overwhelming attention that a similar Crystal Palace was erected in New York two years later.

Parterre: The part of a theater beneath the balcony and behind the orchestra.



CRYSTAL PALACE, LONDON (1851)

The first of a long line of cast-iron structures in America was the Chestnut Theater in Philadelphia, designed in 1822 by William Strickland. Columns were used to support the partierre boxes in the auditorium, but the remainder of the structure was framed with wooden members and masonry walls. Unfortunately this historic building was demolished in 1856.

Strickland also designed the U.S. Naval Asylum in Philadelphia in 1826. (It is still there and was in the process of being restored in 1979.) The great Greek-columned entrance bay is flanked by wings on each side with double story porches supported on a total of eighty-eight slender cast-iron columns. Other materials used in the building are granite and masonry.

One of the most imaginative developers of the iron age of building was James Bogardus (1800-1874). Spanning a period of great activity

in technology. Bogardus was trained as a watchmaker. But his innovative genius drove him to experiment with such widely varied inventions as a mechanical pencil, an engraving machine, and an "underwater sounding machine."

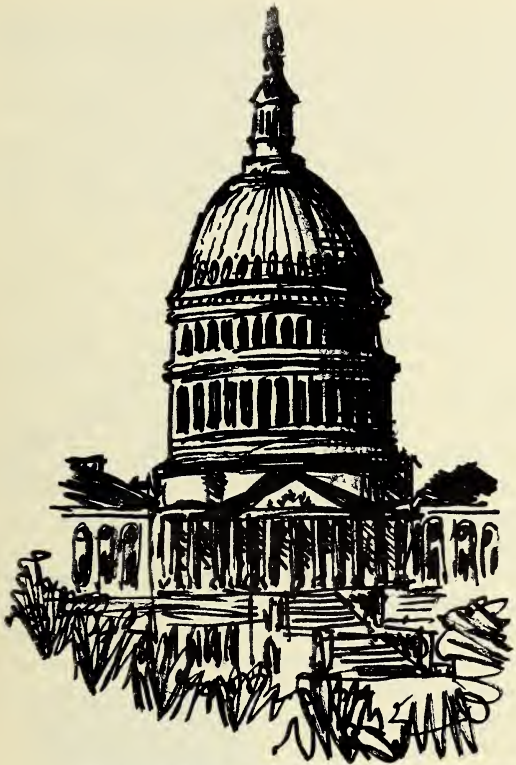
Bogardus' greatest accomplishment, however, was the design and production of mass-produced structural parts for iron buildings. In 1858 he published a book entitled **Cast Iron Buildings: Their Construction and Advantages,** to explain the value of his patented system. A structure of any size, shape, and ornamentation could be built, altered, disassembled, and rebuilt in another form with his products. The advantage of cast iron construction was that standardized components could be produced in quantity. With large scale production came lower cost. The framing members and ornaments produced in factories could be bolted or riveted together at the job site. Bogardus went so far as to suggest that residential as well as commercial structures could be built with this technology. Some of the finest surviving cast-iron buildings are found in New York, Philadelphia, Richmond, and St. Louis; many of them were constructed from materials manufactured by the Bogardus Company.

HARPER & BROS.
NEW YORK: 1854
(JAMES BOGARDUS)

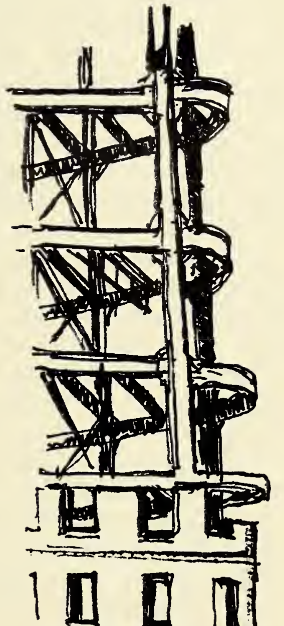
Cast iron continued to be a popular framing material until the end of the Civil War. Thomas U. Walter, an architect of the Capitol in Washington, D.C., combined cast iron and wrought iron in the design of the House and Senate wings in the 1850s. The trusses for the roofs were wrought iron because it was stronger in tension than cast iron. The non-structural trim work, ceilings, windows, and moldings were all cast iron.

After the war rapid expansion of cities necessitated the development of further improvements in massproduction and materials. Carl Condit, who has written in great detail about this period in American technology, said:

> New utilitarian demands and new structural materials and technology radically transformed the large urban buildings. Iron gave way to steel; bearing walls to curtain; masonry fell before concrete; and the craft technique of building was progressively transformed into a scientific technology.



THE CAPITOL DOME
WASHINGTON, D.C. (1855-63)



STEEL FRAMEWORK
CA. 1900

The Home Insurance Company building in Chicago was the first of the modern skyscrapers. Although only ten stories high, it was supported by a metal framework and not by load-bearing walls. Its architect, William LeBaron Jenney, had been an Army engineering officer in the Civil War and received a commission to design "a new type of office building which would be fireproof and offer the maximum amount of light for every room." It was begun in 1883 and completed two years later. An interesting feature about its construction is that it was erected during a transitional period when technology was changing from iron to steel framing. The lower portion of the structure was built with iron while the upper stories were of rolled steel. It was the first time steel had been thus used in a building.

Floors

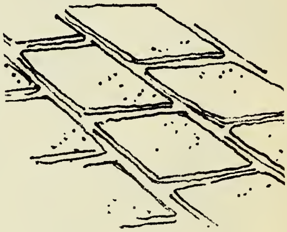
The early houses of America were simply bare-earth dwellings with a covering of thatch for protection against the elements. In the finer homes and many public buildings of the late 1600s and early 1700s, the ground was excavated and brick pavers were put down as a solid floor. But brick floors did not lessen the cold dampness within the house; the floor had to be raised above the ground. The floors were thus made by framing joists into sills and covering them over with smooth planks. If there was a cellar under the house, the main floor was made double-thickness. The sub-floor was rough boarding 1 1/2 inches thick over which the finished floor, usually oak, was nailed. These oaken boards sometimes reached a width of 12 inches, but the expense of the material soon forced the builders to use pine. The latter ranged from 16 inches to 20 inches in width but eventually became narrower, from 6 inches to 11 inches for economy. This last range of widths remained common until after the Civil War.

In the late Victorian era, from about 1870 to 1900, saw and planing mills were turning out special flooring for use in the finer homes being built as a result of new wealth and industrial growth. The flooring, called parquetry, was characterized by small sections of oak, walnut, mahogany, cherry, maple, and other rare woods laid in geometric patterns of elaborate design. The pieces were either fitted together and nailed to a subfloor or were attached by tongue-and-grooves and nailed directly to the floor joists. The first type of flooring was generally 1/4 inches thick, the second type ranged in thickness from 1 to 1 1/4 inches.

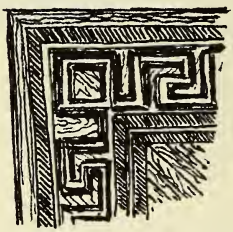
Tiling was another popular means of flooring in some regions of the country. Dating back to the early Roman period, tiling was revived about 1830 when Samuel Wright, an English potter, received a patent to produce mechanically-made tiles. In subsequent years other potteries acquired the patent and added improvements to the manufacturing process. A great impetus for tile manufacture came from the rising popularity of Gothic Revival architecture during the mid-nineteenth century and again with the Spanish

Pavers: Bricks of special composition and dimension (usually square) to serve as paving; designed for hard wear, low porosity, and resistance to frost.

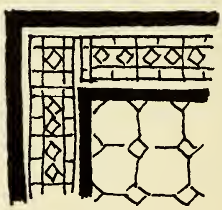
Parquetry: Inlaid woodwork in geometric forms, usually in different colors: used especially in floors.



BRICK PAVERS



DETAIL OF PARQUET FLOOR



DETAIL OF TILE FLOORING

Colonial Revival style in the early twentieth century.

Concrete floors have a long history in building technology and were used in Roman villas and public buildings as far afield as Britain, the northern boundary of the empire. The floors were large slabs laid on brick supports. They were finished with a layer of smooth cement into which mosaics were embedded. Besides stones and glazed tiles, mosaics were made with marble chips mixed with cement to form a solid surface. When smoothed and polished, this was known as terrazzo.

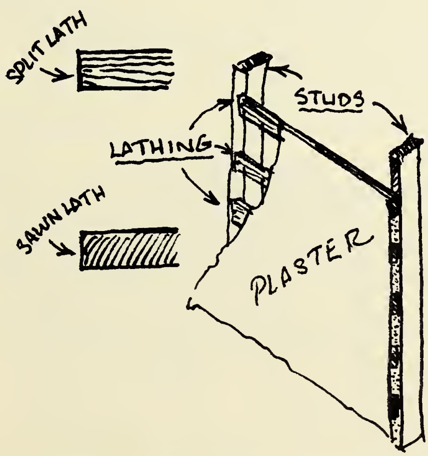
An English patent was given to Denkins Bull in 1633 for a fireproof floor system, but the records give no further details of design or construction to indicate whether it was a significant improvement over earlier treatments. Most of the fireproof floors up to the middle of the 1700s were plastered or bricked underneath, as can be seen below the main floors at Thomas Jefferson's Monticello near Charlottesville, Virginia. In 1778 the Earl of Stanhope, in England, invented plugging as a way to make wooden floors fire-resistant.

> By this process fillets [thin strips] were paled to the joists at about one-third of the height. Laths were laid on the fillets and plastered above and below with a coat of lime and chopped hay. The underside of the joists were then lathed and plastered in the usual way.

Plugging: A material inserted in an opening or hole to stop, make tight or secure.

Fillet: A narrow, flat, raised band running down a shaft between the flutes in a column or along an arch.

Lath: A thin narrow strip of wood used as a base for plaster.



In the first decade of the nineteenth century wrought iron began to be used in preference to cast iron, and in 1830 a floor composed of iron joists sheathed in a fire-resistant packing was designed by Fox and Barret.

Yet the most dramatic use of a fire-proof structural system that was both adaptable to various design requirements and less costly than iron, was reinforced concrete. This material, in which iron rods are inserted into the concrete before it sets, was the invention of Jean Louis Lambot in France. Concrete is very strong in compression but has no tensile strength by itself. By inserting metal rods or cables along the lower portion of the concrete floor or beam the metal adds the necessary tensile strength to the material. With such reinforcement greater open spaces could be spanned without supports. Reinforced concrete is a relatively new construction method, dating from the last half of the nineteenth century. Its full development was achieved by the 1950s.

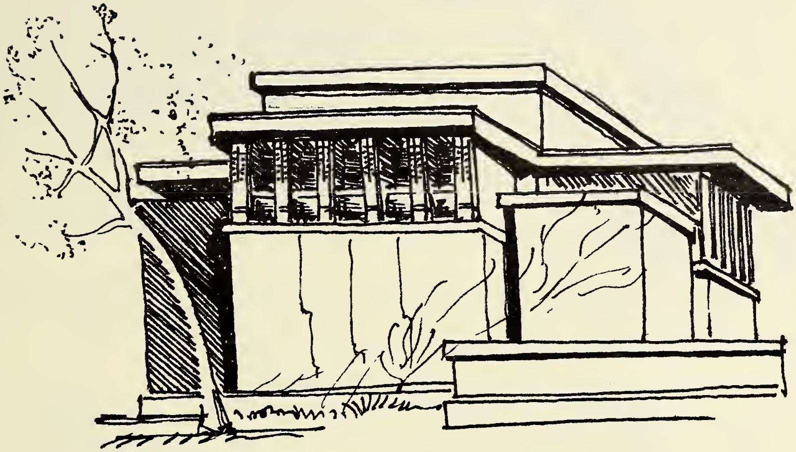
Joseph Monier, again in France, patented a process to prestress Portland cement with steel girders making it possible to construct tall buildings out of concrete. Although poured concrete in wooden forms had been used for many centuries, it was only the addition of metal in the concrete that led to an entirely new system of design and building technology.

Between 1880 and 1892 Francois Hennebique experimented successfully with floor slabs and concrete beams using round bars flattened in a fish-tail form at the ends. These were fitted into iron stirrups that were secured to the foundation. Further development included the "T" section beam and the reinforced piling, the latter introduced in 1897.

Concrete remains a popular method of constructing various building types from houses and churches to schools and office towers. The material is considerably cheaper to make than iron or steel, and through experimentation greater and greater spans have become possible with concrete. E. L. Ransome, manager of the Patent Stone Concrete Company, received several patents for his factory building designs. Beginning with the substitution of tie rods spanning the in-

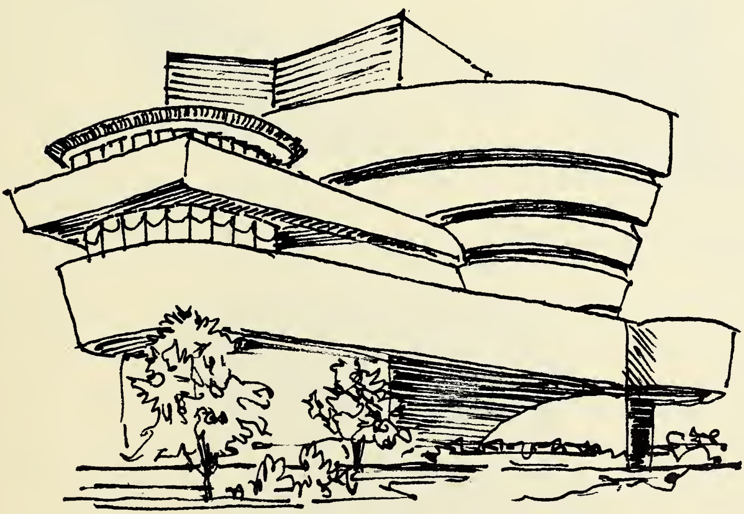
Girder: A strong horizontal beam on which the weight of a floor or partition is carried.

Stirrup: A flat-based ring used as a support.



UNITY TEMPLE, CHICAGO

(1906)



GUGGENHEIM MUSEUM, N.Y.

(1959)

terior space between the walls, Ransome eliminated beams completely and worked out a "system of unit construction" which is used today.

Frank Lloyd Wright also experimented with concrete in many forms throughout his long career. He considered it one of the most adaptable of "natural" materials. From the Unity Temple in Chicago (1906) to the Guggenheim Museum in New York (1959), Wright molded this plastic material into forms that could not be as effective or dramatic had they been made from another product.

Throughout North and South America as well as Europe, architects and engineers have found that concrete structures reinforced with steel rods, called ferroconcrete, could be sculpted into fantastic forms. Perhaps the most striking of these is the TWA terminal in New York's Kennedy Airport, designed in 1952 by Eero Saarinen. Its whole concept is of flowing lines and unencumbered space. The building is as unique structurally as it is visually, for foundations, walls, floors, and roof appear to be a part of a continuous structural unit.

Ferroconcrete: Concrete having an iron or steel framework embedded in it; reinforced concrete.

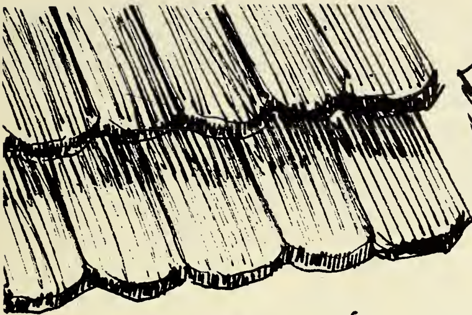
Pantile: A roofing tile having an S curve, laid with the large curve of one tile overlapping the small curve of the next.

Terra Cotta: Burnt clay of uniform and fine-textured material, glazed or unglazed, and molded to provide architectural details.

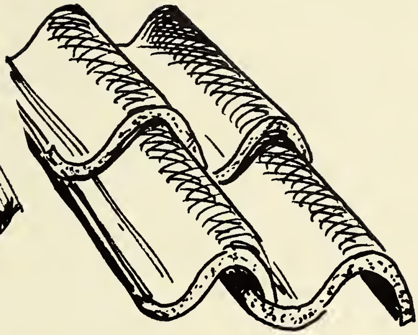
Roofs

Tile was a material used for roofing from earliest times. The ancient Greeks placed white marble tiles on their temples, securing the roof with bronze nails. In Rome and its provinces temples were covered with marble, but less important buildings and dwellings were roofed with clay tiles. In the Middle Ages roofing of cathedrals and churches was generally lead or copper. In Italy pantile or curved terra-cotta tiles have been in continuous use since medieval times. Wooden tiles, or shingles, were in use in Britain before 1066 and made from oak. Slate, too, was used for roofing and siding buildings. An example of the long life of slate is a Saxon church at Stratford-on-Avon, built in the 700s. The original roof is still in place after twelve hundred years!

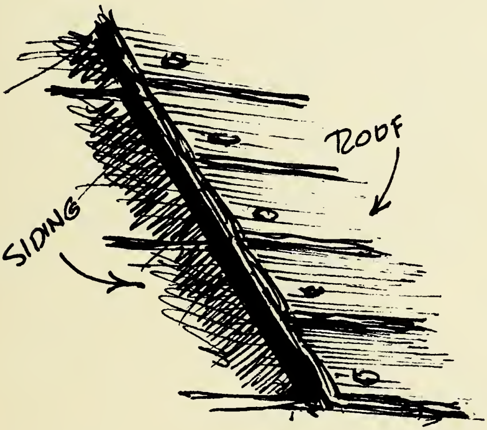
Wales is the region of the British Isles where slate is most prolific. In 1570 reference was made to slate quarries at Penrhyn, Wales, and even before that date castles were covered with slate as protection from assault. During the nineteenth century the building of railways extended the use



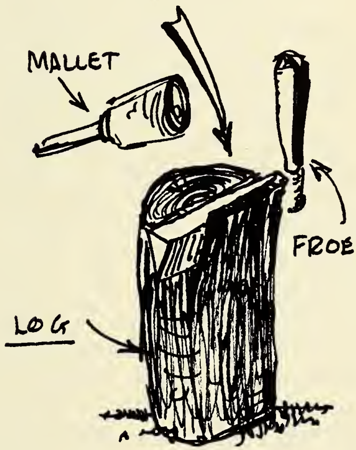
SCALLOPED SHINGLE
ROOF



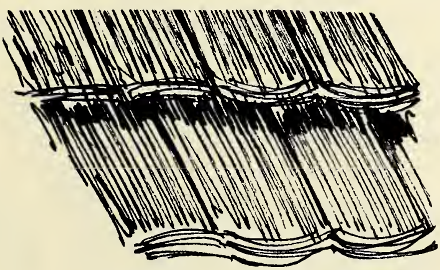
PANTILES



CLAPBOARD
ROOFING



RIVING A SHINGLE



SPLIT SHINGLE
ROOF

of slate from Wales throughout England and abroad.

The earliest slate quarry in America was along the Mason-Dixon line near Delta, Pennsylvania. It was established in 1734. The first quarry in Virginia was opened in 1787, and one was started in Georgia in 1850. Welshmen emigrated to the United States in large numbers to work the quarries during the nineteenth century.

Yet the most universal roofing material in the colonies was wood. In 1640 dwellings in New England were covered, not with the shingles that are so familiar to us, but with clapboards nailed to the rafters. In some areas of the country this method was used at least to the end of the 1800s.

A contract with the builder of the parsonage in Beverly, Massachusetts, in 1656, read: ". . . he is also to find boards and clapboards for the finishing the same with a single covering."

A number of houses built between the late 1600s and the middle of the 1800s along the eastern shores of Virginia and Maryland contain clapboards roofs beneath layers of later shingles. An advantage of the clapboard roof was that it could be installed more rapidly than one of shingles since the long sections of boarding covered a larger area. The boards were about 48 inches long and generally extended across two rafters. They were butted together along the centers of the rafters, and tar or pitch was used to seal the joints. The clapboards added stability to the roof framework and eliminated the need to use purlins (horizontal supports) or shingle laths. But after 1700 the clapboard roof, never as weatherproof as the shingle roof which replaced it, was relegated to outbuildings and barns.

Split or riven shingles were used in the colonies beginning about the same time as clapboarding. In Dutch New Amsterdam the Peter Wykoff house, dating to circa 1640, was roofed with cypress shingles, rounded at the ends and measuring 42 inches in length. By the 1700s the standard size for shingles was 18 to 24 inches in length by 4 to 8 inches in width. The exposure, or that portion of the shingle that could be seen, was usually 6 inches.

The English tradition was to square off the bot-

Purlin: A piece of timber laid horizontally to support the common rafters of a roof.

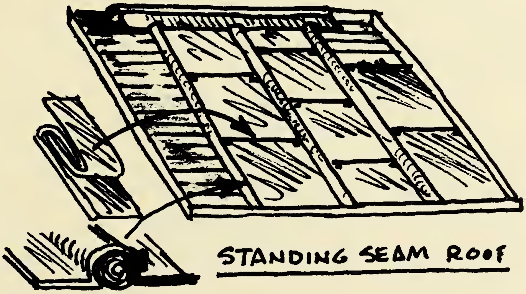
tom of the shingles. On the continent, shingles were rounded or scalloped, perhaps in imitation of tailing. The rounded edges also kept the wood from splintering or warping and eliminated an edge where fire could catch. The Dutch treatment of scalloping shingles was copied in the English colonial settlements during the eighteenth century. By the Victorian period, when shingles were cut in a wide assortment of patterns by machine, rounded and "fish scale" shingles became prevalent again.

Tin, zinc, and copper roofs appeared on buildings from the earliest periods. The initial copper-roofed structure in America was the First Bank of the United States, built in 1795 in Philadelphia. The roof was ordered from England and fabricated in America. Copper rolling mills were producing roofing materials in Maryland and New Jersey in the 1790s. Tin roofing was used in Boston in 1808, and at the University of Virginia at Charlottesville in 1819. Zinc, first manufactured in Belgium at the beginning of the nineteenth century, was used for roofing several buildings in New York City in the 1830s.

But zinc never held the popularity of tin. One historian wrote:

> It appears that American interest in zinc roofing during the nineteenth century ran in cycles of approximately 25 years. About every quarter century, the possibility of its use was raised and discussed. Each new generation apparently became interested, tried it, found it wanting, and then rejected it.

The development of galvanized iron in France in 1836 brought about a new use for zinc as a roof covering. The zinc alloy was combined with iron

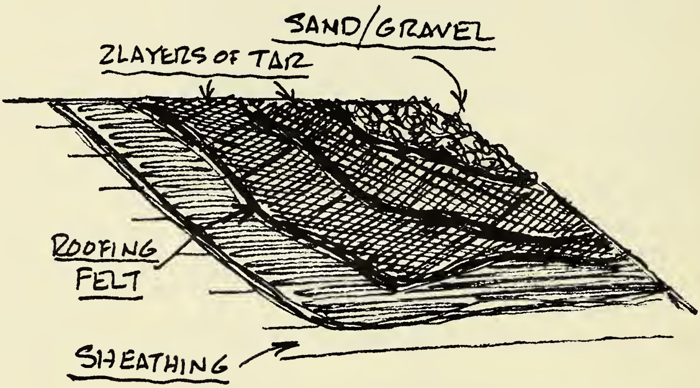


STANDING SEAM ROOF

resulting in a rust-free, rigid material, stronger and more long-lasting than zinc alone.

Composition roofing, developed during the middle of the nineteenth century, consisted of a tar substance poured over felt, heavy paper, or cloth and affixed to the roof sheathing. More tar was poured on top of the base coat and finished with a layer of sand or gravel. Asphalt and asbestos shingles appeared during the early twentieth century. They featured rigidity and long life with a general appearance and scale of the earlier wooden shingles.

Sheathing: The inner covering of boards or waterproof material on the roof or outside wall of a frame house.



COMPOSITION ROOF

Henry Hudson Holly, a nineteenth century architect, summed up the various types of roofs as he saw them in the book **Modern Dwellings** (1878):

> Metal forms the best covering for roofs that are inclined to be flat. Copper is no doubt the best material, but it is little used on account of its expense. Tin. . . answers as an excellent substitute; composition—such as tar or other materials we would not advise on good work, as its only merit is its cheapness.
>
> Split shingles. . . serve their purpose better than the kind known as sawn shingles, as in the former the fibre runs the entire length. . . In sawn shingles, the surface is frequently across the grain, rendering them not only more liable to break, but, the ends of the fibre being exposed, they more rapidly absorb moisture, which induces rapid decay.

During the eighteenth century shingled roofs were occasionally painted green, blue, or black in imitation of slate. In addition, the painted roof protected the wood from moisture and increased its life, provided only the shingles—not the joints—were painted. Holly subsequently advised that each shingle be dipped in the paint and allowed to dry before it was installed. Thus the joints would not be clogged with paint, and the roof would take on a uniform appearance.

CHAPTER IV: EXTERIOR FINISHES

Stretcher: A brick or stone laid lengthwise in a wall.

Header: A brick or stone laid across the thickness of a wall with one end toward the face of the wall.

Course: A continuous layer of bricks, shingles, stones, etc. on the face or roof of a building.

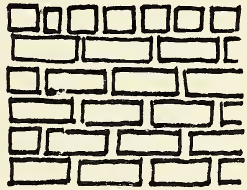
Brick

The most characteristic feature of bricks in wall construction is the manner in which they are laid. This is known as the bond of the brick, an art that has developed over many centuries and in many areas of the world.

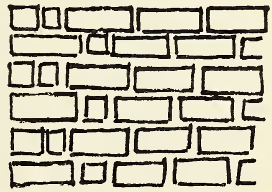
Bonding is important because it strengthens the wall. Whether the thickness of the wall is 8 inches or 8 feet, the system by which the bricks are laid will have an effect on the overall stability and strength of the work.

The earliest type of bonding in the American colonies was borrowed from the British Isles. Called English bond, the work is characterized by alternating rows, or courses, of bricks placed so that the long sides are exposed on one level and ends are visible on the next. The first course is the stretcher course; the second is the header course. By continuing this alternating pattern of stretchers and headers, the wall is completed in "English bond." Every header course is an anchor for the wall because it passes into the thickness of the wall and holds it together. If the wall is thicker than one stretcher, then the bricks are staggered so they will overlap inside the wall.

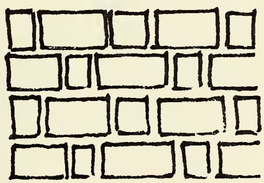
The next method of bonding is Flemish bond. This pattern is more decorative in its appearance because each course is laid with alternating stretchers and headers. Every other course is laid so that the header of one course is centered above the stretcher below it, forming a cross design in the brickwork. Although less strong than English



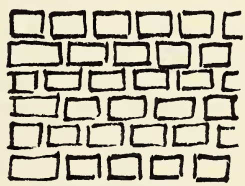
AMERICAN BOND (COMMON BOND)



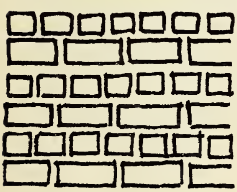
FLEMISH GARDEN WALL BOND (THREE STRETCHERS)



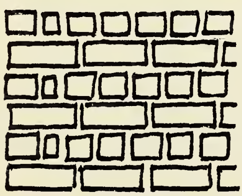
RAT-TRAP BOND (BRICKS ON EDGE)



HEADER BOND



ENGLISH BOND



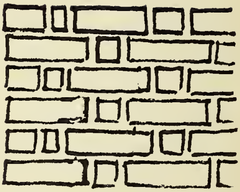
ENGLISH CROSS BOND

bond, the Flemish bond wall creates an artistic and pleasing finish to the wall surface that was especially popular during the Georgian period of building (1720-1810). Early Flemish bond walls were frequently made with glazed headers. The bricks were glazed as a result of the minerals in the clay and their location in the kiln. Parts of the kiln were hotter than others, and the heat could create the glaze. Also, the brickmaker could apply a glaze before firing the bricks and produce a smooth shimmery surface.

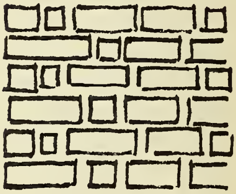
The combination of English and Flemish bond is called Dutch cross bond or English cross bond. It was used to give an even more decorative appearance to the walls. The alternating courses of stretchers and headers are laid in English bond, but instead of the joints of the headers lining up vertically, they are shifted to create a cross pattern in every other brick.

The fourth type of bond is known as common bond and takes several forms. Each system is alike, however, in that the stretchers are built up in several courses, ranging from three to seven, between a course of headers. The one-to-three bond (one header course and three stretcher courses) is sometimes called Liverpool bond or garden bond; the one-to-five pattern is called American bond or common bond.

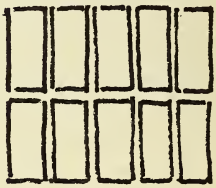
From the 1830s to the present the most popular bond has been the last named, or American bond, because it is easy to construct, has good stability, and is economical. Variations frequently occur, however, in which a wall is composed of different bonds.



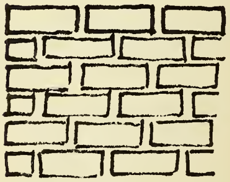
FLEMISH BOND



MONK BOND (TWO STRETCHERS)



STACK BOND



STRETCHER BOND

Stone

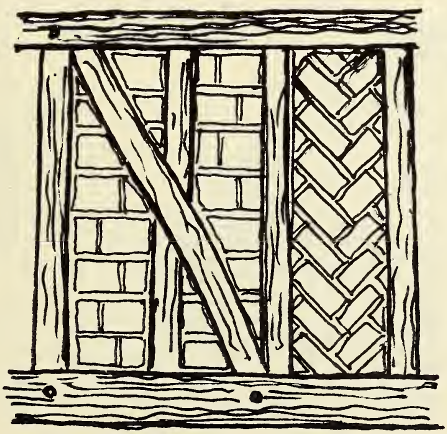
Granite, limestone, and sandstone have most often been used in large cities for buildings designed on a more elaborate scale than those built of brick. In Boston, New York, and Philadelphia ordinances were passed as early as the seventeenth century requiring structures to be built of brick or stone. Stone buildings were especially prevalent in settlements influenced by Dutch and German practices. Examples of these exist in Pennyslvania, the Hudson Valley of New York, Delaware, and North Carolina. Stone and

marble quarries in the East and Midwest produced fine quality material for constructing monumental structures. The art of the stone mason has never diminished since the beginning of time. From the great precision of the pyramids in Egypt to the razorlike edges of the new National Gallery in Washington, D.C., the beauty of stone and marble cut and fitted by skilled technologists belies the weight and solidity of the material.

Nogging: Brick masonry used to fill up the spaces of a wooded frame.

Stucco

Stucco, consisting of a layer of cement plaster spread over a wood or masonry surface, dates back to antiquity. Some of the earliest mudbrick dwellings of civilization were faced with stucco; it was likewise used in Egypt, Rome, Greece, and the Orient. During the Middle Ages half-timber structures were often covered with a stucco material over the brick nogging in the walls of houses. The earliest houses in the American colonies may also have been built in this manner, but the most prolific use of stucco in the United States was during the Revival periods (Greek, Gothic, and Italianate) ranging from circa 1830 to 1870. The material was applied and smoothed in imitation of stone with an additional coating of light sand, giving it a slightly rough cast. Often the stucco was painted to resemble stone or marble.



BRICK NOGGING

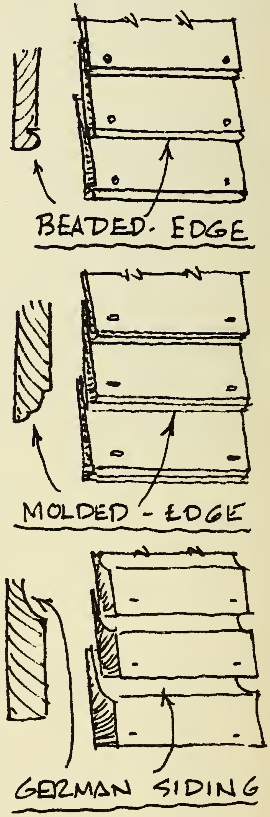
During the twentieth century, and shortly before, the revival of Spanish and Mediterranean architecture became popular in California and Florida, The stucco was laid on in highly textured patterns with names such as Spanish, Roman, and Italian stucco creating a visual romantic illusion.

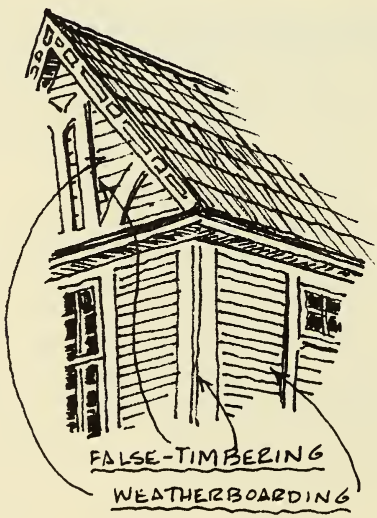
Beaded-edge Weatherboarding: Overlapping boards nailed to the exterior of a frame building in which the lower edges of the boards have a narrow half-round molding.

Wood

The widespread availability of woods of various types in the colonies made wood a principal material for construction. The northern regions of America contained many oak and pine forests; the southern regions contained pine and cypress. Houses were covered with weather-boarding (called clapboarding in New England) that was nailed directly to the structural frame. Sometimes the edges of the boards were trimmed with horizontal grooves, called beads, and later with rounded moldings. This accented the line of the boards and protected the edges from splitting and weathering. Shingles were not used to any great extent on walls because of the additional time necessary to install them over laths and because of their shorter life span.

In the middle of the nineteenth century the interest in Revival styles had its effect on wooden siding. Vertical planks were nailed to sheathing boards against the house frame. Small strips of

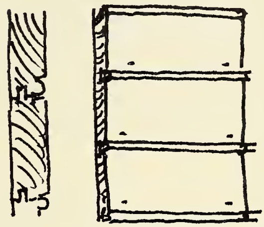




wood were then nailed over the joints of the planks. This pattern, called board-and-batten, was especially popular in rural communities for churches built during the period 1845 through 1870.

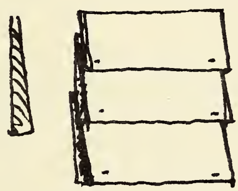
During the Queen Anne period between 1876 and 1900, weather-boarding was fitted between false half-timbering (the Stick style), or combined with shingles cut in a variety of patterns and installed in unusual designs. The wide selection of shapes and sizes gave the material the term "novelty siding."

Half-timbering: A wooden framework having the spaces filled with plaster, brick, etc.

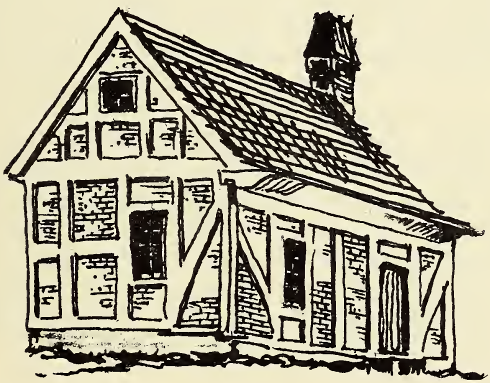


FLUSH SIDING

TONGUE-AND-GROOVE



PLAIN-EDGE



HALF-TIMBER HOUSE

Metal

Metal in exterior work was usually a part of the structural fabric of a building until the nineteenth century. Iron, and later steel, production increased dramatically during the middle of the 1800s and many public and commercial buildings constructed after the Civil War were framed and finished with iron. The cast-iron facades of many surviving buildings in large cities testify to the popularity of the material, often used in imitation of classical orders with details transformed from marble and stone to iron.

The twentieth century brought an interest in new methods of covering structural frames without heavy materials such as iron and brick. Aluminum was used for the cornice work on the

Canada Life Insurance Building in Montreal as early as 1896. Corrugated aluminum was installed as the roofing system at the Chief Secretary's Office in Sydney, Australia, in 1900. The first use of stainless steel was in the tower of the Chrysler Building in New York City, constructed in 1929. Later it provided a wall covering at the General Electric turbine plant in Schenectady, New York, in 1948.

Tile

Tile or terra-cotta is another material that has been used from antiquity. Terra-cotta, like brick, is made from clay that is pressed in molds and baked to a hard finish. Unlike brick, however, the terra-cotta is molded into a variety of sizes and shapes for use as roofing tiles, cornices, and decorative work (sometimes glazed) on walls and floors.

In Italy terra-cotta was a structural material along with brick throughout the Middle Ages and the Renaissance. It was little used in England until the seventeenth century and then only for reproducing classical decorative ornamentation.

The twentieth century brought about a renewed interest in terra-cotta as a building material with the introduction of structural tiles for wall constuction. First used extensively after World War I, such tiles formed the base of structures that were plastered and stuccoed.

Glazed finishes were put on the tiles where weather resistance and clean surfaces were a consideration. The Woolworth Building in New York City, built in 1913, and the Wrigley Building in Chicago, built in 1922, are examples of this type of construction and finish.

In residential work the revival of Romanesque and Spanish architectural styles brought about an increase in terra-cotta and tile manufacture. Frank Lloyd Wright used glazed tiles, worked into geometric patterns, for several of his Prairie houses in the Midwest during the early years of the twentieth century. From the 1920s on Wright used structural tile construction in many of his houses.

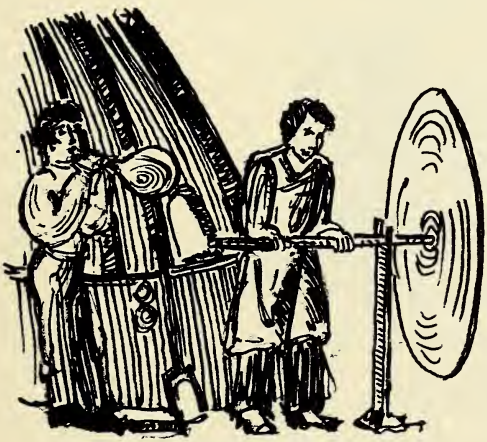
Glass

Glass for windows was used in the Roman em-

pire. Despite its high cost it has always been much desired for its ability to provide light inside buildings while keeping out pests, smells, and bad weather. Glass was formed by fusing silica (a type of sand) with other inorganic materials and then blowing the hot mass into a bubble. Various means were available to reheat and flatten the bubble.

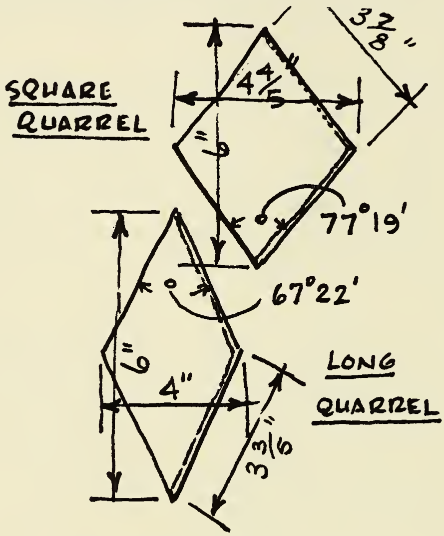
The earliest glass manufacture in the colonies was in Jamestown, Virginia, in 1608. The samples produced were unsatisfactory, however, and the attempt was abandoned. A second unsuccessful try was made in 1621. Until the 1770s window glass was imported from England and France. After that time glass furnaces were established in Pennsylvania, mostly operated by German craftsmen. The Dutch, however, had more success in their attempts, and produced stained glass in New Amsterdam as early as 1638.

While the early windows in America closed with wooden shutters, outward-opening casement windows with diamond-shaped glass panes were soon in use. About 1700 there was a change in fashion to vertically sliding sash windows with rectangular panes. For two centuries after that both the sash windows and panes became larger in size.

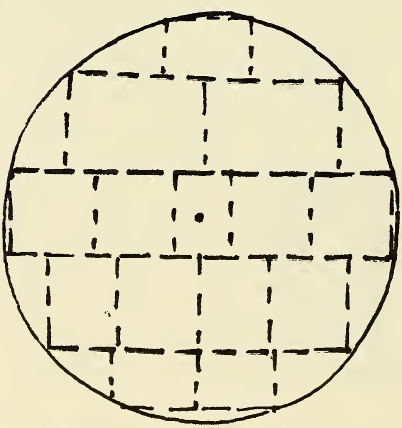


GLASS · MAKING

The most famous of the pre-Revolutionary glass producers were Wistar's in southern New Jersey, in operation between 1739 and 1780; Stiegel's in Elizabeth, New Jersey, and Mannheim, Pennsylvania, producing glass from 1765 to 1774; and Amelung's in Baltimore, Maryland, dating to 1784. After 1792 a glass factory was located in Boston, Massachusetts, which made the window panes for the Capitol in Washington, D.C.



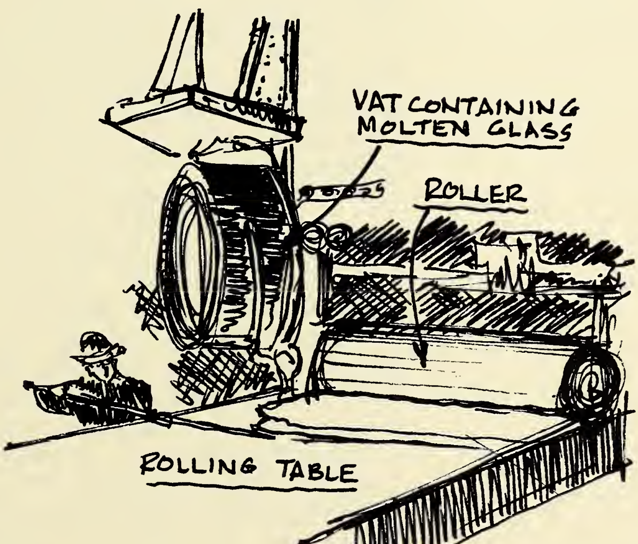
EIGHTEENTH CENTURY WINDOW GLASS



PATTERNS FOR CUTTING CROWN GLASS

In the 1840s special patterned window glass for use in sidelights and transoms as well as "cut and pressed panes for steamboats" were advertised for sale in Pittsburgh and Wheeling. The demand for special leaded and stained glass for churches kept these and other glass-houses constantly active. A Boston manufacture listed among his wares "double thickness glass," "bent glass," and "ground glass" for various uses in skylights, towers, bay windows, and studios.

Plate glass was developed as result of the demand for larger window openings. The standard size glass made until the 1830s was not larger than 36 inches by 48 inches. The reason for this was that any size larger would have to be rolled too thin to be polished. The first plate glass to be made in America was manufactured by the Lenox Glass Works in western Massachusetts. The company was established in 1853 but ended operations less than twenty years later.



MANUFACTURING PLATE GLASS

The glass squares and discs found in sidewalk skylights were the invention of Thaddeus Wyatt in 1856. He installed the glass in steel or concrete, thus forming the ceilings of storage rooms in commercial buildings. Perhaps a development of this design system was the invention of structural glass block which came into vogue during the 1930s and 1940s. It is generally associated with the International or Art Deco style and was installed in both interior and exterior walls. Glass blocks were designed and manufactured by the Corning Glass works in New York about 1932. The blocks are well adapted for use as curtain walls and semi-bearing walls where light without transparency is desired.

CHAPTER V: INTERIOR FINISHES

Wood

Wood has been a common building material for centuries because it is available in almost every region of the world. It can be cut and shaped to almost any desired form, it has great structural strength, and it is found in a wide range of colors, textures, and grains.

Two popular varieties of wood, used from antiquity, are oak and cypress. Both materials have distinct characteristics of their own and were favored in construction of houses, furniture, and ships. Oak had uses other than for building: acid in the bark of the tree was the principal chemical utilized in tanning hides. Acorns were a food supplement for man and beast. The wood was a fuel for brick kilns. Oak when burned gives off a residue called potash which, combined with materials in brick clay and the temperature of the fire, gives bricks a blue-grey glazed surface.

Some of the finest architecture in the world was created with oak. Many great Gothic cathedrals of Europe were roofed with oak trusses and beams that are still in place after nearly a thousand years. In Japan some of the temples constructed of oak and cypress date to the eighth century A.D.

The Egyptians considered cypress to be the wood of death because, once cut, the tree dies. Sarcophagi, or mummy cases; tomb furniture; statues; and other symbolic pieces found in ancient tombs along the Nile were all made from cypress. Because of its resistance to attack from dampness and beetles cypress was also used in making wine presses and musical instruments.

Other hardwoods such as maple, hickory, locust, mahogany, and walnut were used in the American colonies according to availability. Because of the demand for fine woods, the cost of these woods soon rose to such a level that they were affordable only by those with means. Walnut and mahogany were especially rare despite the

fact that the wood was cut into thin sheets—sometimes paper thin—and glued to less expensive woods as a veneer.

Eclectic: Selecting or made up of what seems best of varied sources.

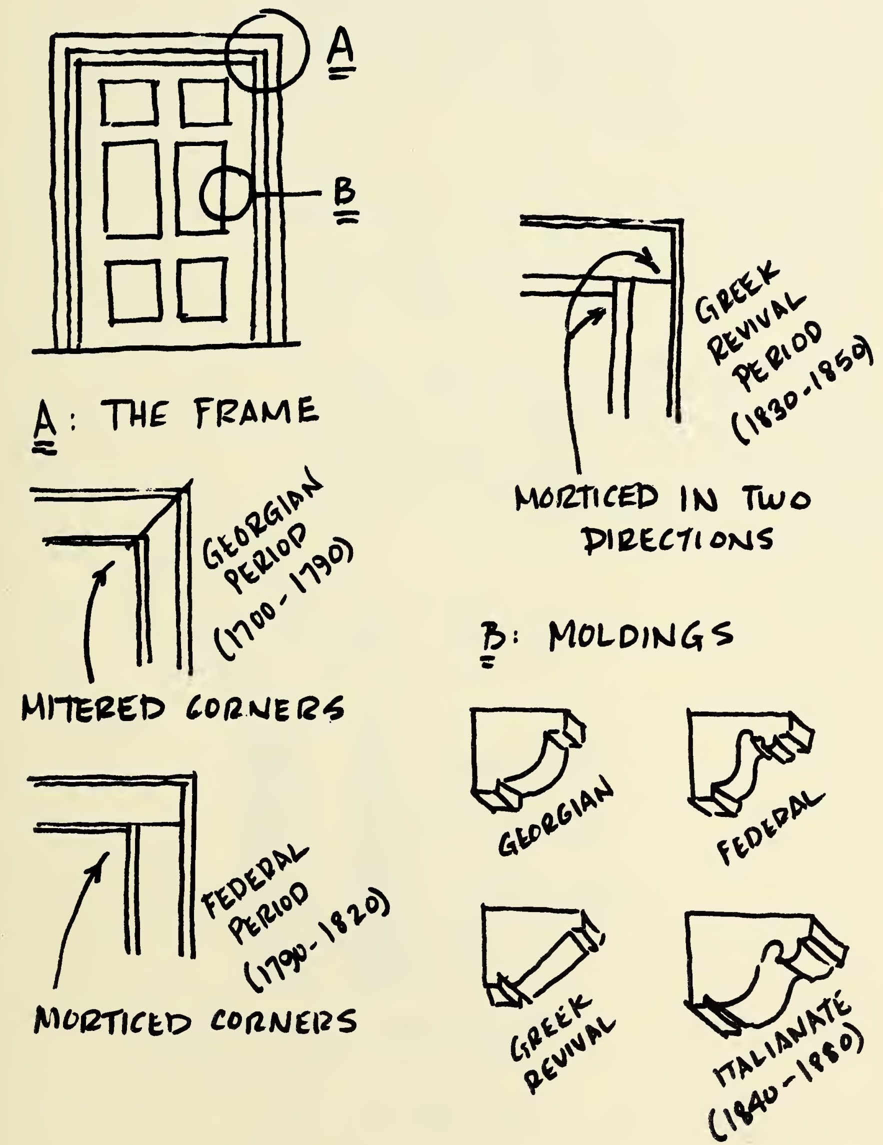
Since pine was widely available in the colonies, it became a basic material for the majority of construction from framing to finish work. Panels, mantels, doors, and frames surrounding doors and windows were fabricated with pine. Instead of covering the material with veneers as was done in the most extravagant residences and public buildings, finishes were accomplished by painting grains on the woodwork to simulate rare or popular woods.

Floors and woodwork in the eighteenth and nineteenth centuries were often painted or stained, but the use of expensive woods for decorative highlights, especially in floors, came into vogue during the late 1800s. Parquetry, a method of inlaying woods to form geometric patterns, was used during the Renaissance in Europe for floors. The rise of eclectic styles in America and abroad in the Victorian era created a demand for both exotic woods and craftsmen to install them properly. Imported woods such as Circassian walnut, teak, African and Phillipine mahogany, and ebony became the boast of many fine houses and clubs throughout the nation.

The search for rare woods continued into the twentieth century. An example is pecky cypress, a wormeaten wood once considered useful only for firewood. In the 1920s Addison Mizener, architect of Palm Beach and Boca Raton, Florida, found that the wood had the ancient timeworn character that he sought. During the 1930s natural woods, unpainted and unvarnished, became centerpieces for otherwise plain and functional architecture. Bleached or blonde woods were popular in the 1940s and 1950s. The influence of Scandinavian designers and architects, such as Alvar Aalto and the Dansk Company reintroduced an appreciation for the warmth and elegance inherrent in fine woods. Frank Lloyd Wright, ever concerned with the natural expression of materials, used woods of various types and textures to create a distinct mood.

An outgrowth of both the desire to produce fine wood finishes and the need to economize was the development of plywoods in the early 1900s. In

addition to having a variety of wood finishes, plywood is valuable for its structural strength. Each layer is glued at right angles to the previous layer, giving the material lateral rigidity.



Plaster

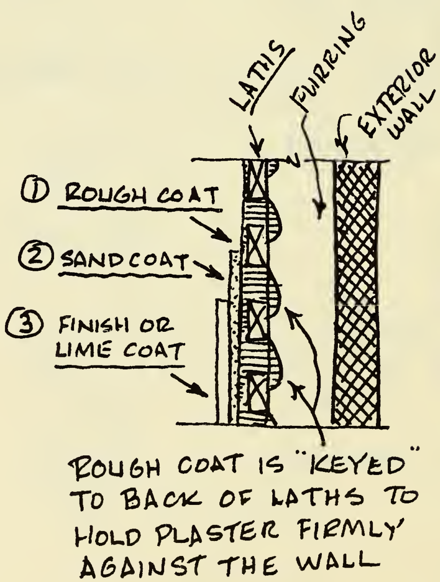
Slake: To produce a chemical change in (lime) by combination with water.

Plaster for interior work was developed to a high level of skill by the Romans and Egyptians. The pyramids and temples along the Nile were finished with a smooth coat of gypsum plaster applied to laths made from reeds tied with cord. According to the historian Pliny, the Greeks plastered their temples with "stuco mixed with milk and saffron, and polished with spittle rubbed on by the ball of the thumb.

Vitruvius in his treatise on Roman architecture wrote:

> The lime should be of the best quality, and tempered a long time before it is wanted for use; so that if any of it be not burned enough, the length of time employed in slaking it may bring the whole mass to the same consistency.

The process of laying on three coats of plaster, a rough coat, a sand coat, and a finish coat, is a modification of the early Roman method. The ancients applied a rough coat on the lath or base material and, while it was still moist, spread sand over the surface. After drying, the second and third coats were applied.



Vitruvius continued:

The sounder the sand and coat is, the more durable the work will be. The coat of marble dust then follows, and this is to be so prepared that when used it does not stick to the trowel. Whilst the stucco is drying, another thin coat is to be laid on: this is to be well worked and rubbed, then still another, finer than the last. Thus with three coats and the same number of marble dust coats the walls will be solid, and not liable to crack.

Sheet Rock: A thin board formed of layers of gypsum plaster and heavy paper used in building walls, partitions, etc.; plaster board.

By the Middle Ages the art of plastering had become a craft protected by guilds or unions. Walls and ceilings were done to a fine smoothness that provided a base for painting and two-dimensional artistry. Not until the Renaissance did the craft reach a new level with three-dimensional, highly decorative work filled with bosses, rosettes, swags, and molded cornices in strong relief.

A further impetus to the popularity of decorative plastering was the archeological discoveries made in Italy, Greece, and Yugoslavia. Details of architecture unearthed in these places appeared in treatises and added a new scientific authority to the field of design. Craftsmen now had measured drawings as guides that could be copied and recopied whenever a particular feature was called for. Thus evolved a standardization of design that came about through archeological investigations into the past and continued during the nineteenth century as an academic approach to the building trades.

The end of World War I brought with it new directions in mass production and building technology. The building booms that occurred throughout the nation during the first half of the twentieth century produced a demand on materials that could be met only with new innovations. Plaster board and sheet rock were introduced in the early 1920s to cut costs and time required to construct a building. But until the 1950s interior finishes were mostly done with wet plaster laid on metal laths rather than wood and finished in a variety of textures.

Tin

Tin is one of the oldest materials known to man. It was among the major exports of the British Isles

during the Roman occupation and has continued to be an important product in modern times.

In the eighteenth century tin was mined in southwest England, northern Germany, and Bohemia. During the next century demand for the mineral caused additional mines to be opened, the most notable site being in Malaysia.

The use of tin for roofing dates to the Middle Ages; later it became one of the important roofing materials throughout Europe and then America. Tin on the inside of buildings, however, was not introduced until the late 1800s when construction activity increased and more mass-produced materials became available. Tin ceilings, really made from galvanized iron, were widely advertised in catalogs and newspapers. The material could be ordered in a broad assortment of patterns and styles from panels to baseboards, chair rails, cornices, and entire rooms. Finishes were available in white, wood-graining, stamped imitation leather (for libraries and billiard rooms), as well as metallic colors.

The sections were easily installed in new construction or over existing work by nailing the seams to wooden strips attached to the structure at one-foot intervals. Once in place, the materials needed little or no maintenance and were fireproof. Manufacturers advertised that these products were ideal for use in hospitals, schools, prisons, restaurants, and offices where cleanliness, permanence, and fire safety were of great importance. However, the market was extended into private residences as well, especially large pretentious homes, with the production of special moldings, panels, and finishes.

Wallpaper

Decoration of interior walls of dwellings with murals was done as far back as 15,000 B.C. by the ancient cave painters at Altamira, Spain. Art as an integral part of a room has thus been a part of human culture from the beginning of recorded time. Every major civilization has its own expression in the form of wall decoration from the human and animal paintings of the Egyptians, Greeks, Romans, and Asiatics to the purely abstract and geometric art of the Arabs and Celts. In Africa and South America mural art has com-

bined animal and abstract forms in unusual patterns.

Because most of the earliest wall decorations were painted on, the cost of producing such art works limited their use to fine homes and public buildings. The middle and lower classes could not afford such luxuries unless they did the work themselves.

The simplest and least expensive way to accomplish this was by the use of stencils. Originally stencils were merely leaves or other natural substances dipped into a color and pressed against the wall. Eventually patterns were cut into heavy paper and sold inexpensively. Many itinerant painters of the eighteenth and nineteenth centuries carried stencils with them as part of their tools.

Wallpaper was introduced in France during the latter part of the 1600s as a direct result of the popularity of Chinese art introduced to Europe at the time. Credit for the development of this decorative mode is given to Jean Papillon. Originally the paper was printed, Chinese style, from wooden blocks and produced in small sheets that were pasted together to form a continuous pattern. By the 1800s machines had been developed to produce "endless" sheets of paper, long rolls of continuous designs in various widths. Papers made in France during the middle of the century were 18 inches wide; English papers of the same period were 21 inches wide with a one-inch overlap; American papers were cut to a standard width of 20 inches.

Early wallpapers made from textile fibers were heavy and long-lasting. Papers made from wood pulp were introduced in England in the 1850s and in America in 1855. The cheapness and short life of the wood pulp (and even later straw) papers made them considerably popular and their use was more widespread than the costly fiber types. Like the tin work of the era, papers of the late 1800s were available in patterns for each portion of the wall and ceiling. The walls were divided into thirds with a wide horizontal border along the top where a cornice would normally appear; an upper wall treatment of a repeating design; and a lower course, where the chair rail and wainscoting would normally be found. Each treatment was

divided by a border paper.

Ceilings were likewise covered with special papers ranging from elaborate imitation coffering to imitation plaster. They were available at various prices according to the means of the patron.

Lincrusta Walton was a specially manufactured wall covering that was in vogue in Europe and America during the period after 1870. It was invented by Frederick Walton, an Englishman, who took linseed oil and heavy paper, producing a rigid three-dimensional paper that he advertised as "The Indestructible Wall Covering."

Flocked papers with a velvet-like finish were made as early as the 1600s. The pattern was pressed on to the paper with a block dipped in linseed oil. Powdered wool was then sprinkled over the paper, adhering to the varnish. The exess wool was then shaken off, and the paper was allowed to dry.

Wallpaper went through a constant evolution because of changing tastes during different eras. The stylistic and exotic scenes of Chinese and Japanese papers of the 1600s gave way to French floral patterns in the 1700s. These in turn were outmoded by the stylized ornament based on both Oriental and floral themes during the Arts and Crafts period of the latter 1800s. Then in the twentieth century Art Nouveau, Cubist and Art Deco styles made their way into popular favor. Finally the process of silk-screening, introduced after World War II, made it possible to reproduce both historical and new papers to satisfy the tastes of everyone at a reasonable cost.

Ceilings

Unless there was an upper floor in early dwellings, the ceilings were constructed from roofing boards or thatch supported by structural timbers. During the classical period in Greece and Rome, ceiling boards and rafters were often painted in floral or geometric patterns. In Spanish-speaking countries this tradition lasted into the nineteenth century and was revived in the 1920s in California and Florida as a distinct feature of Spanish Colonial architecture.

Plaster ceilings did not come about in Europe until the sixteenth century, the late Italian Renaissance in Italy and the Tudor period in

CORNER DETAIL

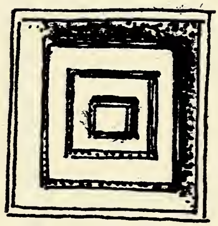
WITH TIN CEILING, CORNICE AND WALLS

Coffer: A decorative sunken panel in a vault, dome or ceiling.

England. The greatest influence for plaster ceilings in America came in the 1700s with the decorative work of Robert and James Adam. The designs were based on scientific investigation of archeological remains in the ancient world with special emphasis on color, form and detail. White predominated in the Adam-designed rooms of Federal period houses, with pale greens, greys, and tans used as accent. Circular and oval shapes were popularized, with scrolls, garlands, and urns worked into the intricate but delicate detail. At times an entire room was built in an oval or elliptical shape. The Adam style continued in favor until the Greek Revival period and was revived briefly in the twentieth century, appearing in private homes, hotels, theaters and office buildings during the 1920s.

At the close of World War I the introduction of sheet rock and plasterboard, wire lath, and ready-made ornamental plasterwork helped builders keep pace with the demand for new construction without losing fine detail and craftsmanship. By the end of World War II, however, simplification of design had changed the market. The traditional plasterer/artison has now become a specialist in repairing and refurbishing old work but must also keep up with the latest technology of mass production.

COFFERED CEILING PATTERN



FLORAL PATTERNS

Bolster: A vise or support for holding a nail shank in place for heading.

CHAPTER VI: HARDWARE

Nails

Nails were produced by hand from the early Middle Ages to the beginning of the nineteenth century. They were made in a variety of sizes and sold at fixed prices per hundred. Our modern practice of designating nails "six-penny," "ten-penny," and "twenty-penny" comes from the medieval classifications according to price and refers to nails of two, three, and four inch lengths.

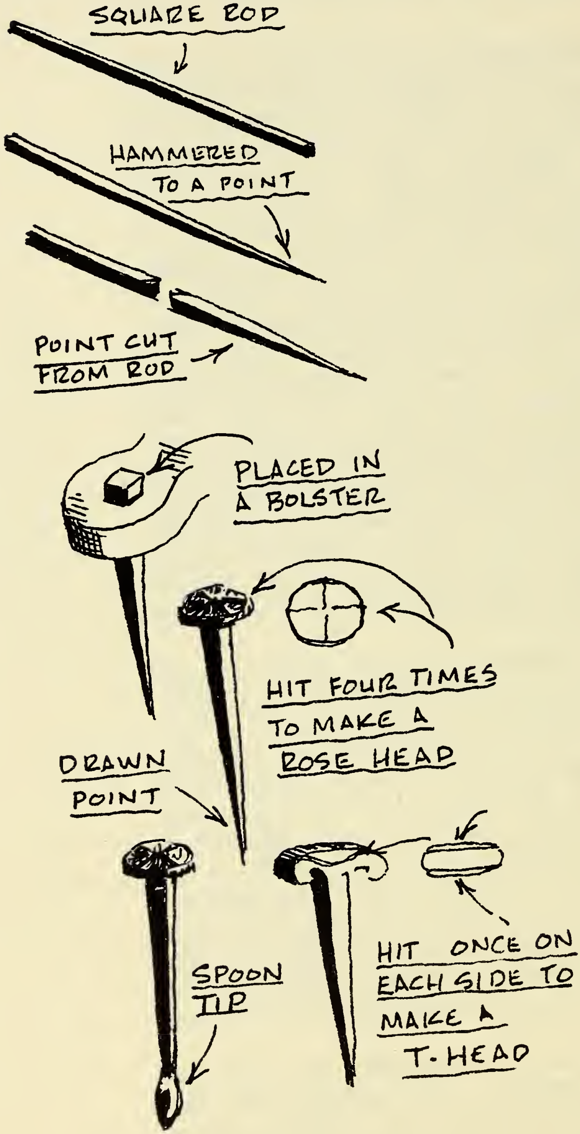
Nails were imported in large quantity to America, primarily from England, at least until the Revolution. One observer as late as 1837 said:

> On account of the greater expense of manufacturing wrought nails, they are sold much higher [than machine-made cut nails]. It is said that nine-tenths of all the nails of this kind, are imported from Europe. We thus depend upon foreign countries for these and many other articles, because they can be imported cheaper than we can make them; and this circumstance arises chiefly from the differnce in the price of labour.

Nails are classified into three types: wrought nails, cut nails, and wire nails. Wrought nails (or hand-made nails) are the earliest. They were hammered and shaped on anvils from stock and were headed by placing them in a vise or bolster. More often than not the building site was also the site for the forge since the rods were delivered in bundles from rolling and slitting mills to be finished by the blacksmith. In the 1790smachines were developed in America and abroad that produced headed nails. William Folsome, in Harrisburg, Pennsylvania, is credited with the production of the first machine-made nails in America in 1789.

Cut nails, made from flat metal plates, fall into periods of manufacture. The first type, made between 1790 and 1820, has noticeable shear marks made by the cutting blade. It was headed in a vise by hand. A plate was fed into the cutter at

WROUGHT NAILS



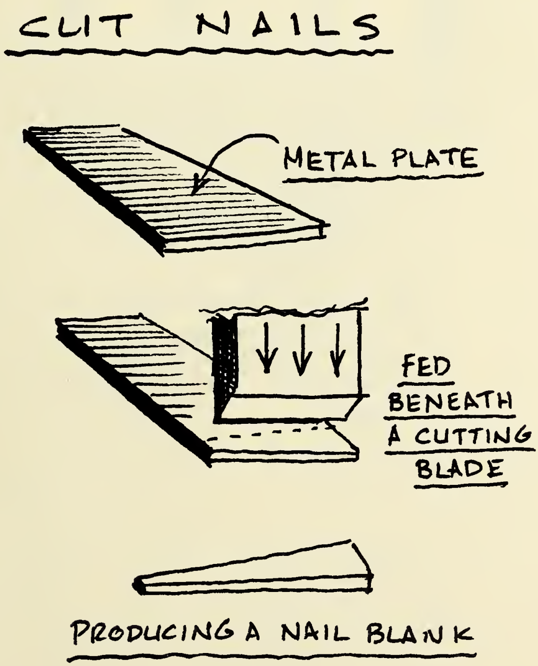
an angle so that the nail blank would shear off in a tapered form. The movement of the blade downdard caused burrs to be raised at opposite sides of the nail shank. To head the nail, the shank was dropped into the vise and struck with a single blow from the hammer.

Shank: The narrow body of a nail between the head and the tip.

The second style of cut nails dates from 1810 to 1820. It is distinguished by shear marks appearing on the same side of the blank rather than on opposite corners. This was caused by rotating the plate as it was fed into the blade. Heading was still done manually.

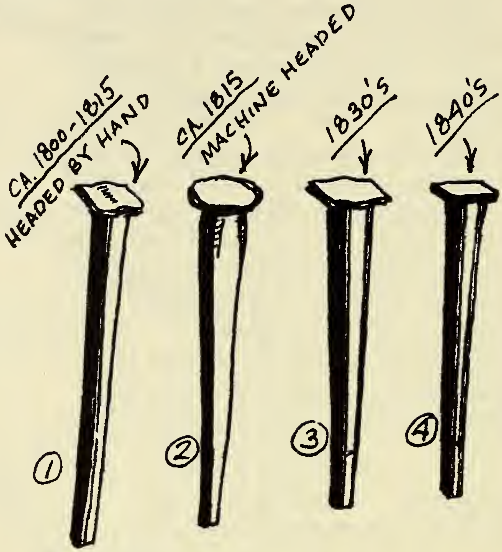
The third variety of cut nails, dating to the 1820s and 1830s, was cut and headed mechanically. Because of the primitive design of the machines, the heads were often uneven and show pressure marks where the blank was gripped by the machine for heading. Shear marks are again at opposite corners of the shank.

The fourth example of cut nail dates from 1830 and is still manufactured today. The shear marks are on one side of the shank, and the metal fibers



or grain runs along the length of the nail rather than across the blank as in earlier types.

The last type of nail is the wire nail, made as early as 1850, but it did not become generally available until the early 1900s. Its use before then was restricted to small items such as picture frames, mirrors, moldings, and furniture.

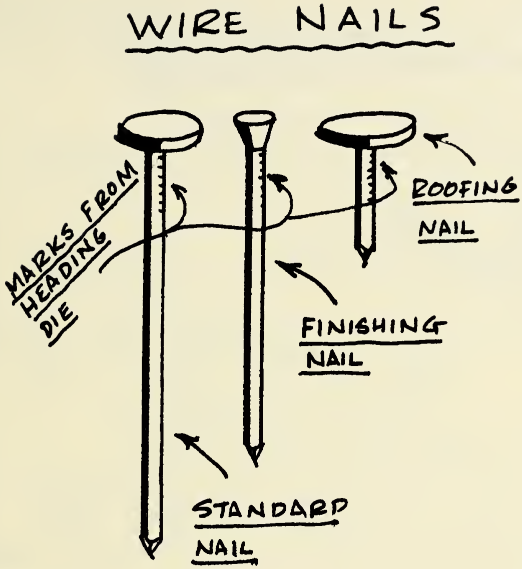


TYPE ① OFTEN HAS AN INCISED LINE ON ONE CORNER.

② NECK IS ROUNDED BECAUSE OF BEING HELD IN CLAMP FOR HEADING.

③ CONVEX HEAD AND UNIFORM TAPER.

④ SMALLER RECTANGULAR HEAD.



Screws

The manufacture of screws, like nails, was the trade of the blacksmith until well into the nineteenth century. Metal screws and nuts appear to have been first used in the fifteenth century. The most common types of heads at that time were square or hexagonal. The T-headed socket wrench was developed during the next century. Early screws were made to fit threaded sockets in military armor and did not become a part of building technology until the mid-1500s.

The wood screw, originally nothing more than a threaded nail, was hammered into timbers for extra holding strength. Once seated, the screw could not be removed. To remedy this the "tournevis," or screw puller, was devised in 1676, making it possible to assemble and disassemble structural members with ease.

The first handmade wood screws were turned with a left-handed thread, which required a counter-clockwise twist to tighten them. The smith kept an assortment of cutting tools that would make several sizes and angles of screws according to requirements. Blanks were the same

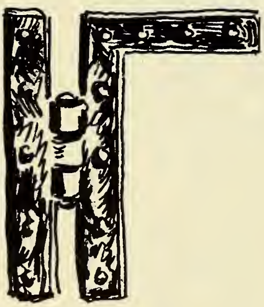
iron rods used in the manufacture of wrought nails, the ends being blunt. In order to seat them, a hole had to be bored into the wood before the screw was installed.

In the latter part of the 1700s screws began to be made by machine. In 1780 London toolmakers produced the long blade screwdriver, called the "London patter," still in use today. Between 1846 and 1848 the blunt-end screw was supplanted by the self-seating pointed screw, invented in England by Nettleford. Thus was brought to building technology yet another valuable tool based on efficiency and precision.

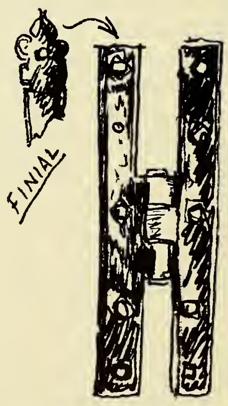
Finial: An ornament at the top of a spire, gable, etc., or at the end of certain structures.

Hinges

The earliest forms of hinges are dovetail, H, and H-L types. Used from the Middle Ages until the end of the eighteenth century, these hinges reached a high level of artistry by craftsmen skilled in producing finely detailed metal work. Until the middle of the 1700s the ends of the H and H-L hinges were often finished with finials and other decorative devices—what Donald Streeter has called "the last vestiges of the Gothic tradition." By the 1750s when the Georgian style had supplanted medieval tastes, metal work became more simplified and functional in appearance.

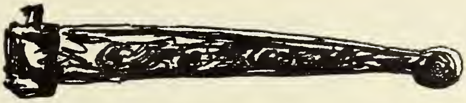


HL HINGE

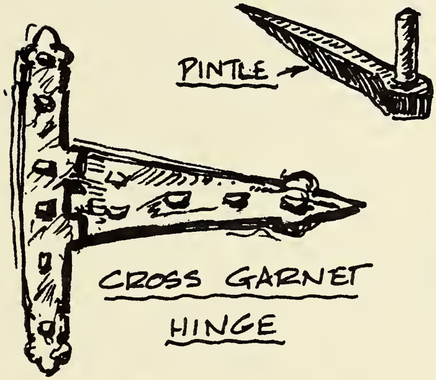


H- HINGE

The shape of the H hinge came about as a result of practicability and has no symbolic meaning whatever. The leaves of the hinge were elongated so that the nails holding the hinge to the door or frame could be kept as far apart as possible. If the nails were concentrated in a small area the hinge would be weakened. The L on an H-L hinge was



STRAP HINGE & PINTLE



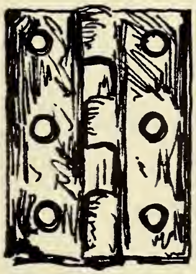
PINTLE

CROSS GARNET HINGE

RISING BUTT HINGE

BALDWIN TYPE

BUTT HINGE (SHUTTERS)



FIVE-JOINT BUTT HINGE

DOVETAIL HINGE

attached to the door where it gave extra horizontal stability along the outer edges of the rails. Sometimes the hinges were morticed into the door, hidden behind the frame molding, and painted to match the door. Most hinges were nailed in place with square leather washers fitted between the nails and the hinge faces. Nails were driven through the door stiles and bent down or clinched on the opposite side for a firm hold.

Hinges were made with five-joint connections until the early seventeenth century. After that time, two-, three- and five-joint hinges were used. The two-part hinge, called the "take-off hinge," was made in some H-L types, but these are rare since they could not be used inter-changeably but had to be fitted to individual swings of doors.

During the seventeenth and eighteenth centuries hinges were mounted on fixed pins. The pins were forged or cast as part of the joint. Later separate pins were made which enabled the doors (or window blinds) to be removed without having to remove the entire hinge.

The butt hinge was invented in England about 1775 but was not much used in America until the early nineteenth century. Butt hinges were cast in molds and were considerably cheaper to produce than the hand wrought H and H-L hinges of the previous century. The screw holes were beveled so that the screws could be tightened flush with the hinges. When the door was closed the flanges of the hinges were covered, with only the joints showing along the casing.

An interesting innovation in the design of butt hinges was the skew joint, also called a rising butt hinge. The joint was threaded or angled upward so that the door rose when opened, and fell when closed. Thus the door cleared the edge of a rug yet provided a tight closure against the floor (an important consideration before thresholds) and was self-closing.

Donald Streeter has written that the butt hinge was one of the great innovations in building technology:

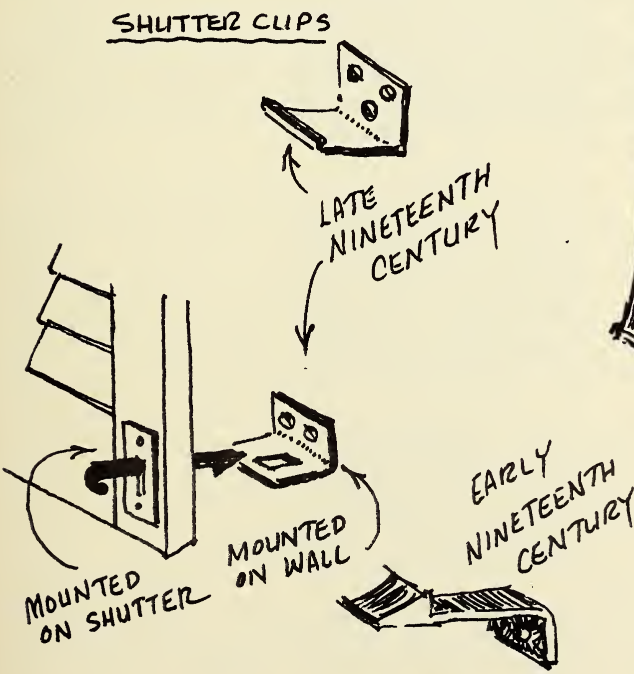
> The case butt was, in its way, as important a development as the inventions of the cut nail, machine cut screw, or the circular saw, in its effect on building construction. No longer need hinges be mounted on the surface with clinched

nails, nor doors be hung flush with the trim, thus allowing deeper molding around them, and calling in turn for mortice locks.

Besides door hinges, mountings for shutters (solid or paneled), blinds (fixed or movable slats), and furniture were produced by hardware suppliers. Early shutters were fitted with strap hinges which were looped over driven or applied pintles. By the 1800s two-part butt hinges, sometimes called Baldwin hinges, were gaining popularity. In both types the shutter or blind could be removed from the structure for repairs by simply lifting it off the pintle.

Pintle: A pin or bolt upon which some other part pivots or turns.

Other shutter hardware was modified during the 1800s because of casting rather than forging. Slide bolts mounted on plates supplanted those held by forged staples. Hold-backs or shutter dogs became less ornamental than the S-shaped type common in the eighteenth century. By the period of the Civil War small plates with vertical clips were affixed to weatherboards, the blind then being pushed over the clips where they were held tightly in place.



Locks

The earliest known locks were in use in Egypt and China about 2000 B.C. In Egypt a wooded lock is depicted on a column carving in the temple of Ammon at Karnak, which was begun in 2466 B.C. The hall in which most of the columnar paintings occur was constructed circa 1300 B.C. In China records indicate that gates of cities were secured with locks having sickle-shaped keys.

From the earliest period locks were designed so that a bolt slid into the housing would activate a series of wooden pins that dropped into depressions in the bolt, holding it firmly in place or locking it. A separate key containing small pegs that matched up with holes in the bolt reversed the action, released the bolt, and allowed the lock to be opened.

The Romans introduced the lock into most of the civilized world with several improvements. The most important of these was the use of springs to operate the bolt.

During the Middle Ages padlocks were designed to be used on chests, wardrobes, and other furnishings as well as on doors. These locks were extremely decorative because the locksmiths worked no longer at a forge but on a bench with a saw, cold chisel, and file to work out their intricate designs. During the 1500s lock designers became much sought after because of their artistic and technical skills.

The introduction of wards or barricades around the keyhole inside the lock was a medieval development which prevented the lock from being opened without a properly fitted key. Keys were filed carefully so they would pass through the wards and release the mechanism. This principle remained unchanged until the eighteenth century.

In 1778 Joseph Braman, an Englishman, invented a lock that used a series of metal plates or sliders to operate the mechanism. When the proper key was inserted into the lock, it aligned the sliders according to a pre-arranged pattern. When all the sliders were aligned the bolt released and opened the lock. In the same year Robert Barron improved the warded lock by notching the bolt and using two (instead of one) tumblers. Up to that time it was possible to force a key through the

wards. Barron's improvement gave double protection to the lock because, if the key passed the wards, it also had to fit the bolt notches. The wrong key would turn up into the notches and jam the mechanism.

Cylinder lock: A roller-shaped lock within the knob and shaft of a door knob.

In 1818 Jeremiah Chubb manufactured a "detector" lock that reduced the possibility of forcing the lock. Any false key that was inserted would cause a spring to release, making the tumbler inoperable.

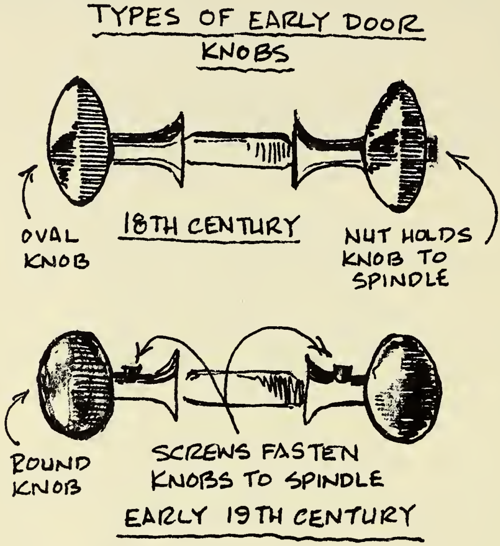
James Carpenter patented a lock in 1830 that was to become a standard mechanism in England and America for the next thirty-five years. Carpenter's lock was basically the same as earlier models with improvements on the bolt design. But the notable feature of these locks was that the latch lifted up instead of sliding into the box when the knob was turned. The lock boxes were decorated with patent seals that made them immediately recognizable as Carpenter style locks. This latter characteristic has made the dating of the lock simpler because the seals were changed about six times between 1830 and 1865.

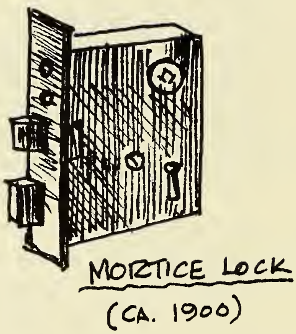
Eighteenth-century locks differ from those of the nineteenth century in the spring design used to move the bolt into its locked position. The earlier type contained a one-piece steel latch bolt spring bent around a screw or rivet. The later type contained a two-piece iron spring held against the rivet.

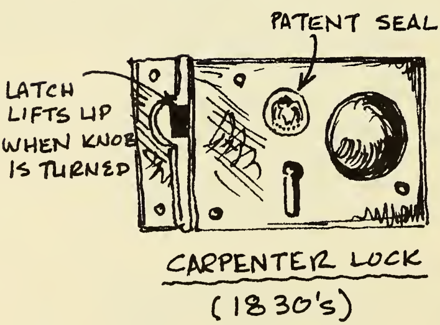
Until the last quarter of the nineteenth century all locks were of the box or rim type, mounted on the face of the door. Mortice locks, concealed within the thickness of the door, were commonly introduced after the Civil War partly in an effort to give a better appearance. However, mortice locks date from the late eighteenth century or earlier. In 1878 Henry Hudson Holly, an American architect, bemoaned the loss of finely detailed hardware that was made to be shown. "Locks, for instance, instead of being in sight, are buried within the wood-work, which is cut away for their accommodation, so as to materially lessen its strength." He called this trend a feature of "these days of modern deception."

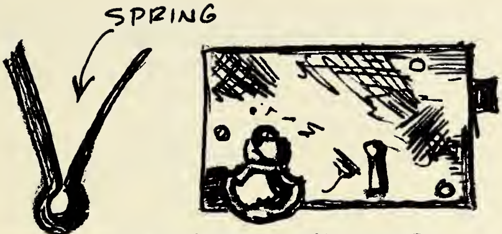
In the early 1920s Walter Schlage, an American lock designer, patented the cylinder lock which contained a push-button locking

device in the knob. Thus the only visible evidence of a lock was in the knob itself.

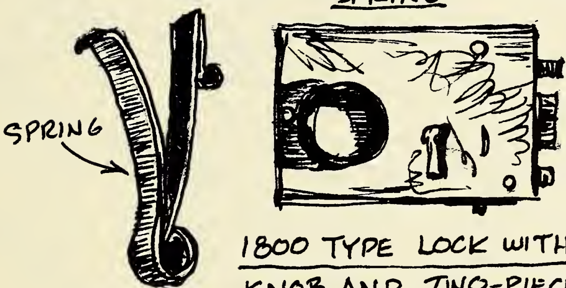




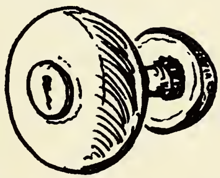




1700 TYPE LOCK WITH DROP HANDLE AND ONE-PIECE SPRING



1800 TYPE LOCK WITH KNOB AND TWO-PIECE SPRING



MODERN CYLINDER LOCK

Gutters and Downspouts

Many of the earliest dwellings in America had no system to carry water down and away from the roof. The first method devised was to pave the ground beneath the drip line of the eaves with brick or stone. This was called the splash and was banked away from the foundation. It also kept water and mud from spattering up on the lower portion of the structure.

In the latter part of the eighteenth century builders began to install gutters along eaves and behind cornices. The Carpenter's Company of Philadelphia published a Rule Book for its members in 1786, containing types of work and prices for materials and labor. In the section on gutters, descriptions were given for plank, lead, copper, and scantling systems installed within the roof and below the eaves. Downspouts, called trunks, were square, semi-circular, or round "to be put together with white lead and oyl."

In his book **The Architecture of Country Houses** (1850), A. J. Downing recommended several types of gutters that could be used to good effect.

Scantling: A small beam or timber, especially one of small cross-section; a small upright timber, as the frame of a structure; small beams or timbers collectively.

The simplest and cheapest was a piece of metal, "copper, tin, or galvanized iron," nailed to the roof to form a trough and angled towards the eaves. For the better class of house the author recommended a copper lined gutter fitted into the rafter ends, supported by brackets, and finished along its edge with a molding.

Calvert Vaux wrote the following comments in his architectural style-book **Villas and Cottages** (1864):

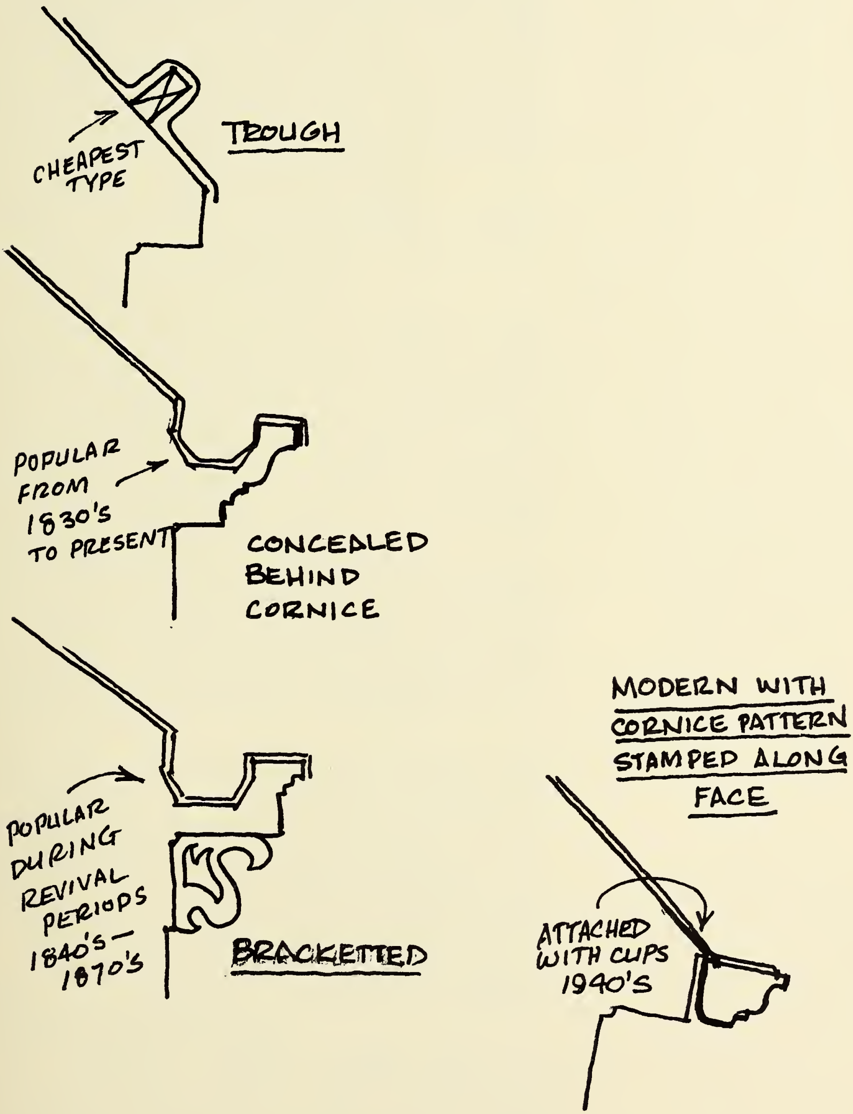
> Rain-water pipes, as generally planned, are most unsightly accessories to a country house. . . .Instead of being circular, as generally made, they should be semi-circular, so that they may rest flat against the wall surface; and they should also be fitted with heads, and the pipe that conveys the water from the roof should be carried into them with a curved line from the level of the gutter, instead of being cut through the cornice in the common, slovenly, broken-backed way that disfigures nineteen out of twenty country homes in America.

The main problem about concealed gutter systems was that the metal work deteriorated inevitably because of lack of inspection to clear away leaves and other debris. Overflow or leaking through the gutters brought water into the walls or attic, resulting in costly repairs to the entire fabric of the building. In many cases the dampness attracted termites to the wood members. The introduction of detachable gutters and downspouts, mounted at the eave line, helped alleviate this problem but maintenance was still an important consideration. Aluminum materials and continuous gutters with a minimum of joints helped control deterioration to a considerable extent. Because of the added detail the gutters gave to the eaves, manufacturers produced "eave troughs" in several patterns to imitate cornices. This treatment, first appearing in the late 1800s, became the standard for economical construction by the 1920s.

Preventive maintenance is an important part of all construction and, whether the drainage system is through concealed or visible means, lack of attention will inevitably bring about costly repairs. A trend toward the early treatment of omitting gutters and downspouts completely and providing a splash along the foundation has been revived in

the 1970s, suggesting that the knowledge of past practice considered out-dated in later years may be reapplied to modern technology.

TYPES OF GUTTERS



Plaited wick: A lamp wick that is pleated or braided.

CHAPTER VII: LIGHTING

Artifical lighting has been a feature of our lives from the beginning of civilization. Early man carved shallow depressions in stones or molded saucer-like vessels in which he burned animal fats and oils. Wicks were simply reeds or fibers placed in the fat and ignited. The resulting illumination was a flicker of light accompanied by heavy smoke and the odor of burning grease.

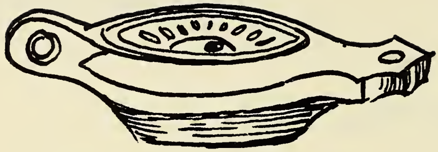
Neither the Greeks nor the Romans directed their skills to developing this technology as they did with so many other sciences.

The "Betty lamp" which the Pilgrims brought with them to the New World in 1620 was not unlike the most archaic lamps. Instead of being stone or pottery, the Betty lamp was cast or wrought iron with a spout on one side to hold the wick in place and a handle or hook so that the light could be attached to a chair or wall as required. The Betty lamp burned fish oil readily available in coastal settlements.

Candles, of course, had been used since the Bronze Age, but the laborious process of dipping the wick into hot fat until a useful candle was formed often made it impractical for general use. The fluid lamp continued to be used until the introduction of candle molds in the fourteenth century.

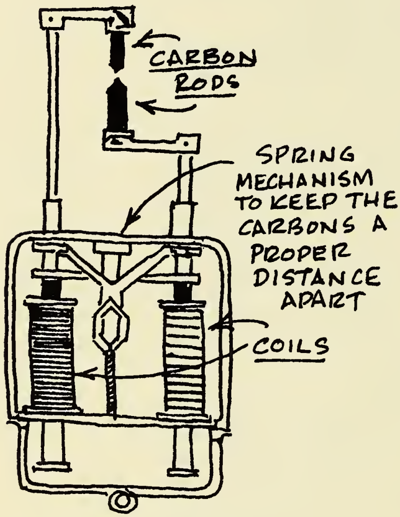
A problem inherent in all wick-burning lights was that carbon collected at the tip, causing the flame to sputter and go out. The wick, therefore, had to be periodically trimmed or snuffed. Candle snuffers were not, as is often described, implements to put the candle out but rather scissors-like tools to snip off the carbonized end of the wick. The elimination of this procedure came in 1825 when a Frenchman, Cambaceres, devised the plaited (braided) wick.

The eighteenth century brought with it experimentation with various types of lamps and fuels. Benjamin Franklin is credited with inventing a twin-wick lamp which could produce a flame

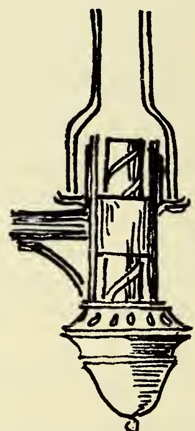


ANCIENT "LAMP"

"BETTY LAMP"



THE CARBON ARC LIGHT



ARGAND LAMP

brighter than one with two separate wicks. In 1783 Aime Argand designed a lamp with a tubular wick inserted between double rings. The outer ring contained the fuel and the inner ring contained air. By properly mixing fuel and air the light burned efficiently and brightly. Argand also invented a glass chimney to control air drafts as well as a method for regulating the height of the wick.

The fuels that were tested during this period included naphtha, a distillate of coal first used in

1784; coal gas, made from coal tar in 1820; and the combination of coal gas and oxygen. The latter method was developed by a German, Robert Wilhelm von Bunsen, whose laboratory bunsen burner is still in use today.

The most popular lighting fuel during the first half of the nineteenth century was whale oil. Until the discovery of petroleum in the 1850s the sperm oil industry flourished to such an extent that the whale population became severely depleted. Spermaceti candles, made from a wax processed from whales, were stronger than tallow candles and burned with a brighter flame. They were extremely popular and kept the whaling trade active. As whales were killed off, spermaceti candles became very expensive. Cheaper paraffin candles became available about 1860, and kerosene (a distillate of petroleum) replaced whale oil in lamps.

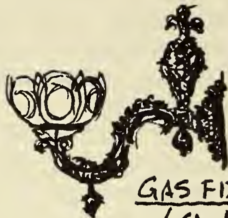
Gas Lighting

Experimental production of gas from various sources for illumination occurred throughout the second half of the eighteenth century, but it was not until the nineteenth century that central generating plants were established. The first practical demonstration of gas lighting was in Paris residence in 1801, when Phillipe Lebon showed that gas could be used effectively on a large scale by the use of his Thermolamp, which was fueled by coal gas fed through a metal tube and ignited. The following year his invention was brought to England by Frederick Albert Windsor. Then ensued a period of competitive experimentation that resulted in the establishment of the National Light and Heat Company in London in 1812. By 1814 the city streets were lighted by gas lamps, and five years later 288 miles of mains had been installed bringing gas service to 51,000 burners.

Windsor was responsible for initiating central generating plants and a system of underground pipelines supplying gas to individual subscribers. Watt and Boulton had proposed setting up separate gas generators in each house and factory, but this proved impractical and Windsor's system prevailed.

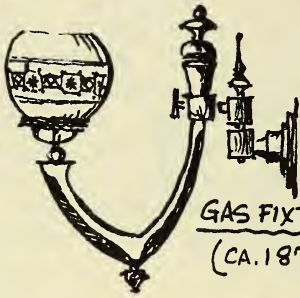
In America the first city to plan for a gas generating plant was Philadelphia in 1815. But,

GAS FIXTURE
(CA 1815)

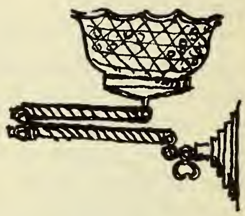


GAS FIXTURE
(CA. 1860)

GAS FIXTURE
(CA 1820)



GAS FIXTURE
(CA.1876)



GAS FIXTURE
(Ca 1905)

due to a number of difficulties, the system was not put into operation until 1835. By that time both New York and Baltimore had established their plants.

James Marston Fitch has written:

> By the time of the Civil War, an entirely new concept had appeared in building design: that of a fixed, semi-automatic lighting system which freed the building from its historic dependence upon natural light.

Gas was popular in homes, and fixtures and accessories were available from mail order houses such as Sears and Roebuck at the turn of the century. Early fixtures and piping systems were exposed but later piping systems were built into the structure of the building. Pipes were brought underground from the main in the street to the building and to a meter. From the meter or other valve system pipes were run inside or outside of walls to service kitchens, stoves, and wall fixtures.

The fixtures for illumination evolved from simple openings at the end of a pipe controlled by stopcocks to elaborate chandeliers and lamps. The 1902 Sears catalog shows combination gas

and electric wall and ceiling fixtures and even a portable table lamp.

Gas service was available only in urban areas with generating plants. City dwellers of modest means could afford this steady means of illumination. Bright and steady light for rural areas had to await the coming of electricity.

Electric Lighting

Perhaps the most significant discovery in the field of artificial light came with the invention of the incandescent bulb. As early as 1841 experiments were being made in France and England to develop this type of light source. But the experiments were unsuccessful for a number of reasons. The greatest difficulty lay in finding the right kind of filament to burn in the bulb. It was not until 1878 that Thomas Alva Edison found that platinum wire, coated with carbon, caused the lamp to glow for an extended period of time. His success was due to a tireless study of the properties of electricity and various substances that could be used in producing a useful result. He identified the factors necessary to produce light from electricity as:

1) The substance to be heated must be carbon in the form of a thin wire rod or thread (the filament);

2) The filament must be supported and enclosed in a vessel formed entirely of glass;

3) The vessel must contain a vacuum;

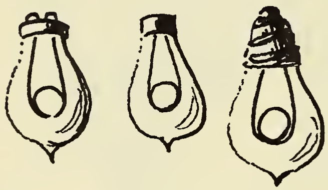
4) Current must be conveyed through the glass to and from the filament by means of hermetically-sealed (airtight) platinum wires.

EDISON'S FIRST ELECTRIC LIGHT (1879)

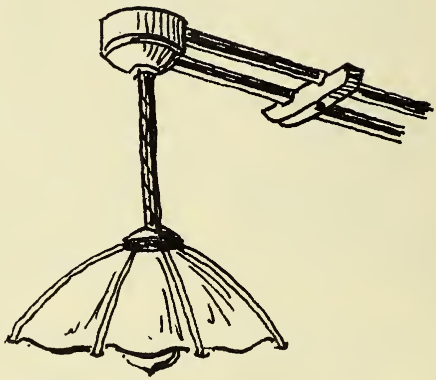
Edison had originally produced a bulb containing a bamboo filament carbonized by baking. By the early 1900s the carbon filament was made by spraying a hydrocarbon through a dye, letting it harden, and then carbonizing it. By the mid-1920s the platinum filament had been replaced by copper and nickel. In that decade tipless bulbs were introduced, the vacuum being produced through the filament system. During that period frosted bulbs also were made, diffusing the light and producing a more even light.

Wiring

Edison's first electric generating plant was put into operation in 1882 and supplied direct current through underground conductors to customers living near the plant. Because the current was direct and low in voltage, the system was not efficient over great distances unless a step-up transformer was used to overcome voltage drops along the lines. In the same year a Frenchman, Lucien Gaulard, and an Englishman, John Gibbs, invented the transformer. In 1885 William Stanley developed a transformer for use with alternating current in which high voltage was sent through small conductors over a wider geographic area.



TYPES OF LAMP COLLARS
(1910)



THE KNOB-AND-TUBE WIRING SYSTEM
(1880's — 1920's)

The first commercial electric generating plant to use alternating current was built by George Westinghouse in 1886 at Buffalo, New York. Ten years later a plant was in operation in Buffalo driven by water power from Niagara Falls. By 1905 Syracuse, New York, 150 miles away, was receiving electric service from the Niagara plant.

The first wiring to be used to bring service to a building was bare stranded copper supported on porcelain insulators. The poles were either wood or iron. In cities the wiring was enclosed in india rubber for protection. Interior wiring, likewise in-

sulated in rubber, was waterproofed with varnish and placed in wood casing. By 1910 aluminum wiring was being produced.

The wiring of a residential building consisted of a service wire brought from the pole to a service head on the exterior of the building. From this point wires would be run into the various rooms for illumination and other outlet services. The wire was strung over walls and framing members using porcelain cleats. Another early method was to drill a hole in the building facric and insert a porcelain insulation tube for the wire to pass through. A hole was drilled in the existing wall, and the tube was inserted for insulation and protection against fire. The wire by the turn of the century was two strands roped around each other. These early wiring materials are called knob-and-tube wiring. It was a light-weight system not designed to carry heavy electrical loads. The switches and fuses of early electrical installations were similar to what is used today. There were basic switches: the knife blade and the pole switch, or snap switch.

Electrification eventually reached every corner of the country; aspects of that history are beyond the scope of this work.

CHAPTER VIII: MECHANICAL SYSTEMS

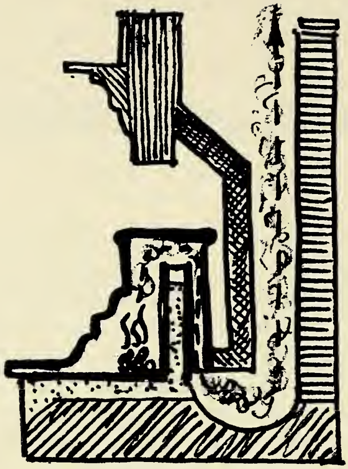
Heating

The earliest type of heating was an open wood fire. Fuel was easily collected, but warmth did not radiate more than a few feet, most of the heat rising with the smoke into the upper air. A solution to the smoke came with the discovery that, if the wood was first made into charcoal, it could be rekindled and burned without the tell-tale smoke column. The problem of heat loss remained, however, and it was not until about 600 B. C. that the Chinese devised a stove to contain the fire, concentrate the heat, and conserve fuel. The discovery spread slowly along the trade routes between China and Russia, Scandinavia, and Germany. Although the stove did not completely replace the open fire until the late nineteenth century, its value was appreciated in cold climates.

Further steps toward the elimination of the smoking fire came in the thirteenth century with the invention of the chimney flue, but until fireplaces were designed to direct warmth into the room the heat escaped up the flue with the smoke.

In 1744 Benjamin Franklin, attempting to deal with smoky fireplaces and drafty rooms, brought forth his "Pennsylvania stove," designed according to scientific principles. The stove was built to fit into an existing fireplace with only a few modifications. Franklin added a hollow metal air box at the back of his stove to draw cold air in from the room and send warm air out into the room. Fire and smoke passed along the outside of the box on the way to the chimney, heating the box and the air inside it. The heated air passed through vents into the room, drawing more cool air into the bottom of the box to be warmed in turn. The inventor wrote:

> Your whole Room is equally warmed so that People need not croud [sic] so close round the Fire, but may sit near the Window, and have



THE FRANKLIN STOVE
(1744)

the Benefit of the Light for Reading, Writing, Needlework, &c.

They could also enjoy watching an open fire without suffering its shortcomings.

One of Franklin's close friends was Benjamin Thompson, later known as Count Rumford. He, too, wanted to improve heating systems and wrote a scientific treatise on design and construction of fireplaces that would supply heat and remove smoke effectively. The book, entitled **Chimney Fireplaces with Proposals for Improving Them to Save Fuel, to Render Dwelling Houses More Comfortable and Salubrious, and Effectively to Prevent Chimneys from Smoking,** was first published in London in 1795 and reissued in 1969 as **The Forgotten Art of Building a Good Fireplace,** a classic in the field of building technology. Rumford designed a shallow fireplace with a new flue system to provide more heat to the room.

Heating was also a function of building design. Early buildings in colder climates had to have a fireplace in each room to be heated. The chimney was often inside the structure to provide warmth and protect it from harsh weather. Windows were small and usually very few or non-existent on the

side of the building facing the prevailing wind.

The major shortcoming of fireplaces and stoves was that only one room could be warmed per fire. The central heating systems of today were still in the future during the eighteenth century. But oddly enough, central heating goes back some two thousand years before Franklin and Rumford.

The earliest known central heating system was installed in Greece about 350 B.C. Soft coal or lignite was used as fuel for a fireplace beneath the structure. A series of horizontal flues or ducts were laid under the floors and in the walls. Similar to Franklin's later stove, the ducts were warmed by the gasses passing through them and radiating the heat into the room.

The Romans further developed the system, called by them a hypocaust. Floors were constructed as slabs resting on piers, the entire area beneath the rooms being a continuous flue connecting the furnace with hollow-tile chimneys in the walls. In the Italian provinces the hypocaust was principally used for public baths. In outlying districts and in Britain it was installed in public and private places alike. Fuels used by the Romans included charcoal, brushwood, and coal.

By the beginning of the nineteenth century, with steam engines and steam-generated power, attempts were made to channel the heat produced by the engines into the chill air of the factories, schools, and homes. Originally the steam was brought to buildings through pipes suspended from ceilings. The boilers were made from wrought-iron plates riveted together and enclosed in brick. The problem with the system, however, was that it was effective only at high heat and pressure levels. The hot surface areas of the pipes gave the surrounding area a parched feeling, "accompanied by a disagreeable odour of burnt dust." In 1831 John Perkins invented a new high-pressure system using a continuous circuit of thin pipe. The coils in the furnace were of the same material. This closed system of heat became popular almost immediately because of its greater efficiency and better appearance, the small pipes being less noticeable than the heavy and cumbersome cast-iron pipe of the earlier steam and gravity hot water systems.

The earliest type of radiator was a coil of iron

pipes enclosed in a metal box with holes in it. Finned pipes were installed in most factories and greenhouses. Sectional radiators that could be added to according to the area to be heated date to the middle half of the nineteenth century. Originally constructed of cast-iron, they were later made of steel.

Another early system of heating was gravity hot water. Hot water, like hot air, rises if given the chance. Water was heated in a closed system of pipes and radiators and circulated through the system because the hot water rose to the radiators and there passed its heat into the surrounding air. Then the cooled water sank back through other pipes to the furnace in the basement for reheating. By the 1830s and 1840s many buildings in England and America were heated with this method. The major drawback of the system was the large inside diameter of the pipe (over 3 inches). This made the installation cumbersome and ugly. The pipes of the steam system were easier to fit into a building and could get hot enough to start a fire.

At the beginning of the nineteenth century heating by hot air carried through flues or ducts beneath the floors was revived. The Houses of Parliament in London, built in 1837, were equipped with a carefully designed system in which fresh air was drawn from the Thames River side, purified, heated by means of steam, coils, and delivered through small holes drilled in the floor of the House Chambers. The exhausted air rose to the ceiling where it passed through flues to a chimeny containing a continuously burning fire. The fire produced enough suction to exhaust the air through the chimney to the outside.

A. J. Downing, in his book **The Architecture of Country Houses** (1850), expressed reservations about hot air heating systems, preferring hot water as "the most healthful and perfect mode of heating buildings yet invented." His preference was based on the fact that in a hot-water system the heat was warm, "never either hot, or loaded with the **flavor** of cast-iron." The drawback of his system was its cost, being about five times as expensive to install as hot air.

Throughout the remainder of the nineteenth century and into the twentieth, improvements in

central heating were focused on the furnace itself. Methods for controlling the heat within the firebox and the use of oil and gas for fuel led to more economical plants. In large cities district heating was introduced whereby a central system provided heat for an entire block of houses or for several large buildings. The first installation of this type was in Lockport, New York, in 1877. New York, Detroit, and Chicago soon followed suit. The majority of the plants were generated by steam.

The heat pump which has received much attention since the 1960s was first suggested by Lord Kelvin in 1851. Its principles of operation is that it acts as a refrigerator in reverse. Air from the outdoors is pulled into an evaporator where energy is added by a compressor, raising the temperature to the desired level. By reversing the cycle, air in the room is drawn through the pump where it is cooled, thus reducing the inside temperature. The heat pump, working in two cycles, acts as both a heater and an air conditioner.

Cooling

Before the addition of mechanical cooling systems, providing a comfortable environment in buildings was accomplished by design. In the Spanish Southwest buildings were built with thick adobe walls and ceilings as well as open courtyards and arcades. In the South buildings had high ceilings and roofs plus large windows and central halls to provide breezes. Porches also helped furnish needed shade. Cooking was often done in separate buildings, and chimneys were placed outside of the building.

Electric power, available since the late nineteenth century, turned fan blades to cool homes on hot days. Fans came in many sizes and shapes, but perhaps the most widely recognized was the large bladed ceiling fan.

Early air conditioning systems in use around the turn of the century cooled air by blowing it past, over, or through a curtain of water. The air would then be ducted into the space to be cooled.

The word air-conditioning was first used by Stuart Cramer in a paper presented in 1907. His discussion was concerned with the control of humidity in cotton mills and led to further studies in balancing temperature and humidity in large

spaces. In 1911 Willis Carrier published the results of research into the air conditioning of public buildings. His first air conditioner was built in 1902, and the Carrier Corporation was founded in 1915.

Related to air conditioning was refrigeration for the preservation of food and the manufacture of ice. In 1862 Dr. A. Kirk developed an air machine which produced four pounds of ice from a pound of coal by operating in a closed cycle. In 1877 a compressed-air machine was designed by J. J. Coleman and installed aboard the ship **Circassia,** carrying perishables between America and Britain.

Until the 1920s water-purifying ventilators rather than refrigerating systems were used for cooling buildings. The greatest surge of interest in cooling came during the mid-1920s with the growing popularity of motion picture theaters. The first fully air-conditioned building was Graumann's Metropolitan Theater in Los Angeles, equipped in 1922 by the Carrier Corporation. The success of the system made certain a new technology in climate control. Air conditioning by cooling air with freon and a compressor spread into buildings of all sorts and even to autos, trains, and airplanes. It has been said that, without modern air conditioning, the development of tall buildings in temperate climates would not have become a reality.

Insulation

The need to protect inhabitants in a dwelling from both heat and cold is one of the basic principles of building technology. From the time man began to build his own shelters he was concerned with protection from the elements, and many of his solutions to the problem were universal.

One of the earliest forms of building insulation was known as wattle-and-daub. The wattle was a basket-weave of twigs and small branches, such as willow or hazel, fastened between the upright supports of the structure and coated or daubed with clay or plaster. This form of construction has been found in houses in Asia, Africa, Europe, and pre-Columbian America. The system also was brought by early settlers to the New World as part of their technological knowledge.

Another type of insulation is brick nogging. After the frame of the house was constructed, the interstices, or spaces between the timbers, were filled with sun-baked or lightly burned bricks and the surfaces coated with plaster stucco. In some cases only the interior was plastered, the exterior being covered with weatherboards. Brick nogging is a characteristic of medieval construction and the half-timbered house. Half of the structure is wood frame, and the other is solid fill.

A third method of insulation is solid walls. The walls can be of almost any material—masonry, adobe, stone, wood. An interesting solid wall construction is tabby, found in parts of the West Indies and the Atlantic coast of the South. Tabby is loosely consolidated marine life pored into forms like concrete to form thick walls. The density of the wall absorbs the heat of the sun and does not allow it to penetrate to the interior.

Still another form of insulation is quilting. Made from a marine plant, Zostera marina, the quilt was stiched between strong paper and sold in rolls. The first manufacture of the product dates from about 1900, but it was used in New England as early as the 1600s. Quilting seems to be the forerunner of batt insulation that is manufactured from fiber-glass today.

Sawdust, sand, cork, and even paper are other forms of insulating material that have been found packed into walls of old houses to give additional protection from the weather.

Each of the above methods is similar in that the material in the walls could trap air within the substance. In log construction, the mass of wood was the insulator. In plank construction, the thick boards created a dead-air space within the wall cavity. As long as the walls were tight the transfer of heat and cold was minimized. This is the basic principle of insulation: to provide a barrier between two dissimilar surface temperatures. Modern insulation has the additional characteristic of providing a vapor barrier to control dampness in the wall cavity.

CHAPTER IX: PLUMBING

Water Systems

In the ancient world several important cities were equipped with sanitary systems that were the pride of their day and a source of admiration in our own time. Aqueducts carried water from great distances to supply the needs of the residents of Jerusalem, Athens, Rome, and Carthage. The aqueduct in Jerusalem is the earliest known to exist, dating from 727 B. C. Athens had an underground system 4,200 feet long built with lead pipe. It was completed about 625 B. C. The Romans built aqueducts by the hundreds throughout the Empire which extended into Italy, Spain, North Africa, France, and England. The longest of these, constructed in 145 B. C., was 56 miles long and was one of eleven that carried water to Rome. It has been estimated that 350 million gallons of water per day flowed into Rome during that time.

The purpose of constructing aqueducts was to transport fresh water from mountain lakes and streams to urban centers that lacked their own supply. Most cities had polluted their own waters because of bad drainage and over-population. By bringing in water through elevated sluices, pressure also was built up so that residents living at second-and third-story levels could be supplied.

In other places, water wheels were used to raise water from reservoirs to aqueducts. Although Archimedes had shown that his screw principles could move water vertically, it was not applied to any extent by the Greeks or Romans in their systems. In fact, until the invention of the water pump, the water wheel continued to be used for moving large amounts of water. The first pump was built in Hanover, Germany, in 1527; another was installed in London in 1582.

Throughout the period that elapsed between the fall of Rome and the Middle Ages many of the aqueducts fell into disrepair. In 1183 a new

aqueduct was built to serve the city of Paris, and in 1235 an underground system, using lead or terra-cotta mains, was installed in London.

Both lead and terra-cotta pipes were used throughout Europe until the sixteenth century. But expense and scarcity forced builders to find other materials. Hollow wooden pipes bound with iron straps were used in London in 1589.

In Boston, the water system installed in 1652 and extended in 1796 was comprised of wooded piping. The Philadelphia water system was constructed with spruce logs before 1804. When it was replaced with cast-iron pipes, the wooden mains were sold and were reused until 1887.

By the mid-eighteenth century running water from these urban water systems was being extended into key buildings and even individual dwellings. Spigots provided water for drinking, cooking, and washing.

Sewers

Sewers have also evolved since antiquity. The earliest sewer system of any consequence was built in Rome between 800 and 735 B. C. The outflow led into the Tiber River. The city of London did not have any sewer system other than open ditches and cesspools until the fourteenth century when the king ordered a sewer installed in the Great Hall of the Westminister Palace. The sewer that was built led water underground to the Thames just upstream from the spot where drinking water would later be drawn for the city! The original sewers of Paris were constructed in 1663 but those now in use, more than 750 miles in extent, do not predate the nineteenth century.

There was no standard rule for construction of sewers until the mid-1850s. Most of the drains were irregular culverts of brick, stone, and rubble. They were porous and frequently overflowed into neighboring wells and cisterns, spreading pollution and disease. In Paris a cholera epidemic in 1832 was traced to a contaminated well. London suffered epidemics in 1832, 1849, 1853, and 1854 from the same cause. This led to a recommendation by the General Board of Health that the sewers be rebuilt by "reducing the dimensions and altering the shapes of the old stone and brick structures." Thereafter sewers and drains were

lined with ceramic pipes.

Indoor Fixtures

One item we often consider to be a modern invention is the water closet. But as early as 1586 Sir John Harrington, godson of Queen Elizabeth I, wrote a tract describing a valve closet that would wash out the drain so that "your worst priuie [sic] may be as sweet as your best chamber." Harrington's invention featured a cistern and a flow pipe controlled by a valve. He wrote: "At noone and at night, emptie it, and leaue it halfe a foot deep in fayre water." In the following year the design was installed at Richmond Castle to the great satisfaction of the royal household.

Not until 1775 were any further improvements made in the water closet. In that year Alexander Cummings, a British inventor, received a patent for a water closet with a trap or water seal. Three years later his patent was rivaled by Joseph Bramah, another experimenter, who had earlier invented the hydraulic jack. Bramah's patent was for a water closet with a valve at the bottom of the seat. Modifications of these patents were used in America in 1833.

Perhaps the most important developer of the modern toilet was Sir Thomas Crapper who added innovation and expertise to sanitary engineering. Beginning in 1872 with a patent for a cistern that conserved water, called the Valveless Water Waste Preventer, Crapper went on to develop the disconnecting trap, a water seal that was installed between the waste pipe and the main drain. Following this he received patents for a smoke-generating machine for inspecting leaks in soil pipes and a water closet with a concealed operating mechanism for use in prisons.

By the second decade of the twentieth century the cistern for the water closet had been moved from a position high up on the wall to the level of the seat. In the late 1930s the commode and cistern were unified into one fixture.

Other sanitary equipment developed during the nineteenth century included a practical residential bathtub, the shower, and the lavatory. The first bathtubs were carved from marble and were too heavy to be installed in private homes. Public baths dating to Greek and Roman antiquity, such

as the baths of Caracalla built in 212 A. D. in Rome, were the models for public facilities for centuries. With the desire for privacy in bathing during the 1800s, smaller fixtures were introduced for private residences. The hip bath was manufactured in the 1850s, the shower bath was produced in the 1880s, and the pedestal sink was introduced about 1900. By 1910 most bathroom fixtures were made of porcelain or enamelled copper and tin. The advantage of porcelain was that it was easier to keep clean. Its disadvantage was that it was a bad conductor of heat.

The design and installation of bathroom fixtures evolved slowly between the 1850s and 1880s, with most of the early fixtures concealed in architectural enclosures and wainscoting. Bathtubs, originally built into cabinets, were supported on raised legs during the 1890s and enclosed in porcelain from floor to rim by 1916.

CHAPTER X: COATINGS

Paint

The earliest examples of the preparation and use of paint come from the Paleolithic period (before 10,000 B. C.) when animals were depicted on the walls and ceilings of caves. The most famous of these are at Altamira, Spain, and Marsoulas, France. The paints were made from berry juices and earth pigments mixed with water. Several hollow horns of bone found at the sites contained powdered colors stored for future use.

By the fifth century B. C. paint colors, made from earth pigments, ranged from ochre to red and brown. Copper sulfate and malachite produced green and blue hues, and a record dating from 350 B. C. documented the manufacture of white lead.

From the earliest examples of painting through the centuries to Colonial America paint was a decorative and artistic medium. The development of paint materials for protection is directly related to artistic painting and decoration of products such as coaches and ships as well as religious and government buildings.

Oil-based paints using a medium of linseed oil did not appear until the 1500s. They were first produced in Flanders and later brought to Italy.

Oil and lead based paints were the standard until the twentieth century. The paints applied to houses in the eighteenth and nineteenth centuries were composed of lead, zinc, or some other pigment; oil; color; and additives such as extenders and dryers. The painter usually had to buy his supplies from others and then grind and mix them into a usable liquid. Each painter had his own recipes and theory on what was a good paint.

Thomas Child, the first professoinal painter and paint manufacturer in America, was granted the rights and privileges of the London painters' guild in 1701. He brought with him to Boston a paint mill, later known as the "Boston stone," to grind

pigments. The mill consisted of a stone sphere 20 inches in diameter that fit into a stone trough three feet long. The pigment was put into the trough and then ground with the sphere into a fine powder.

In the eighteenth and early nineteenth centuries a common way to grind pigments was in an iron kettle using an iron ball. Hezekiah Reynolds' book, **Directions for House and Ship Painting** (1812) instructed:

> Take a smoothe iron kettle of middling size, and an iron ball weighing from 12 to 24 pounds; and suspend them in some convenient place, by a rope or chain; put into the kettle from four to six pounds of paint dry, and grind it until thoroughly pulverized.

Although the Greeks and Romans used color in the interiors and exteriors of their buildings, painted interiors were not common until the middle of the eighteenth century, walls being whitewashed and woodwork being rubbed with oil rather than painted. The Georgian style of the eighteenth century brought about an interest in painted and grained surfaces. Both exterior and interior painting was done in three coats, the first and second being primers. Spanish white and Spanish brown or red lead were common primers, and it appears that linseed oil was used on the wood before the primers were applied. A British account dating from 1723 recommended that new wood be primed:

> with Spanish Brown, Spanish White, and Red Lead (about a 5th part) to make the other two colours dry, well grown'd with Lintseed Oyl, will make excellent Primer.

Painting buildings was difficult because of the way paints were mixed by the painter. It was hard work and dangerous to one's health. In the 1860s there was a revolution in the painting industry. The introduction of paint ready mixed in cans made house painting much easier. The result was that paint and colors became an item that could be mass produced, shipped, and marketed across the entire country. The ready mixed paint caused a change in color taste because paint companies could advertise and deliver a rainbow of colors. The danger of lead poisoning from breathing paint vapor and getting it on the skin was not solved un-

til 1974 when lead was removed from paint. Also, the paint industry remained in large part an empirical art until the advent of standardized mixtures in the twentieth century.

Stains

Staining did not become a practice in finishing wood until the mid-nineteenth century except for roofs and doors. Stains are made in thin transparent liquids, the vehicle being water, methylated spirit, size, turpentine, and linseed oil. Some stains using alcohol, acid, or alkalai were designed to raise the grain of the wood as well as color it for special effects.

A popular way to create special effects in houses of the eighteenth and early nineteenth centuries was to grain the wood by painting an imitation of rarer types of wood. Walnut, mahogany, oak, maple, and a variety of exotic woods were simulated over pine and cypress. A ground color was applied and allowed to dry completely. Then a second coat, thinned with oil or turpentine, was brushed on with a flat brush or specially designed grainer's comb. When the top coat was dry it was covered wth a thin application of copal varnish. Mantels, baseboards, and other trim work was often marbleized in much the same way as graining.

During the Revival periods of the 1840s graining came under criticism from designers such as A. J. Downing. He believed that stains were better suited to the decor of houses and villas than graining. Of staining he wrote:

> Pine treated in this way is so strikingly like the plainer portions of oak or black walnut, as to produce the same general effect at first sight, while a closer examination shows only the real grain and texture—unlike the painted and grained surface, which is only an imitation.

During the 1920s and 1930s a revival of grained and distressed woods came into fashion in an effort to create a feeling of great age in the wood. But by the period of World War II, natural finishes had returned to favor. In the 1960s and 1970s a new kind of wood finish, a thin veneer or machine produced pattern, came on the market. Sometimes referred to as "K-Mart panelling," the material is an example of mass-production and a

growing scarcity of finer natural woods.

Varnishes

Varnish is a gum extracted from fossilized trees. Originally called copal, the earliest source of the material was East Africa. Trees containing copal were found by probing the ground with iron spikes and digging the deposits for cleaning and processing. Later fossil gums were discovered in the Phillippines (called Manila gum), Indonesia, and India (called damar gums).

Varnish was produced in ancient Egypt and has been used continuously into the present. Until the twentieth century the method of manufacture was closely guarded, and it was only through chemical analysis that synthetic varnishes were devised.

The monk Theophilus in the eleventh century wrote a recipe for varnish as follows:

> Put Linseed Oil into a small new pot and add, very fine powdered, a Gum which is called Fornis, which has the appearance of the most lucid. Thus, but when broken, it yield a bright lustre. When you have placed over the fire, cook carefully, so that it may not boil up, until the third part is consumed, and guard against the flame, because it is very dangerous and is extinguished with difficulty if it is raised. Every painting, covered over with this Glutten, is made both beautiful and forever durable.

Early varnishes were used to protect artistic paintings. The varnish provided a hard, smooth surface that prevented paint from smearing, rubbing or washing off, or deteriorating from exposure to sunlight. Early varnishes were also used on unpainted wood for ships, coaches, and other products which received hard use.

On buildings varnish was and is used for exterior protection of doors and other trim items. Varnish is fairly hard and in certain recipes could be used on floors. The formulation of varnish remained an empirical method until the twentieth century and the development of coatings science.

CHAPTER XI: REGIONAL CHARACTERISTICS

Building Traditions

Throughout the long history of building technology there have been traditions in the builder's art that have bridged the ages. From the first man-made habitations to the present day, materials and methods of constructing dwellings have not evolved as much as one might expect.

Despite the wish to be innovative and progressive, the history of building is remarkably dependent on past fashions and formulas. The Greeks, Romans, and Egyptians created finely proportioned and monumental architecture but based their construction techniques on past forms. Shelters built of wood, straw, clay, and stone were transformed into marble and brick, but the evidence of post and lintel framing remained. In the Middle Ages braced frame construction developed in Europe because of the accessibility of timber.

Gothic architecture during the Middle Ages was innovative, however, in its attempt to bring together the vertical and horizontal parts of a building into a flowing unit. But the forms, reminiscent of a tree with its sheltering branches, can be traced also to archaic building traditions where the vertical supports were bent and tied together to form the roof and walls. Even the vault was borrowed from earlier Roman forms.

During the Italian Renaissance in the fourteenth century and continuing to the beginning of the twentieth century, building traditions were strongly dependent on the past. The influential and carefully detailed manuals of Pollio Vitruvius (active 46-30 B.C., Andrea Palladio (1508-1580), Sebastiano Serlio (1475-1554), William Halfpenny (d. 1755), Robert (1728-1792) and James Adam (1732-1794), and James Stuart (1713-1788) and Revett, although written in several different centuries, all dealt with a restudy

of historic architecture and technology.

Building tradition is, therefore, a most important part of the understanding of the evolution of building technology. Once a basic pattern of construction was developed it held fast, being modified only by development of new tools and streamlining of parts.

When builders travelled to new places, they carried with them the techniques they understood. If they were worthy of their trade they compared their own technology with those of others, modifying and changing their craft according to ideas new to them. If their own techniques were better, they influenced others in the trade.

Whatever style or design a building may show, the underlying clue to the training of the builder is the way he erected the structure. The traditions that he understood reveal where he came from and how strongly his trade was instilled in him.

Development of Local Methods

The development of local methods of construction, known as regionalism or vernacular architecture, is a characteristic of most of the architecture of America and elsewhere. Settlers to the New World came from many areas of Europe and held fast to strong traditions from the homeland. It has been said that the settlement pattern of New England is different from that of the South because of the different regions from which the emigrants came. Those who settled in the North and along the coastal area of the South were of English stock, used to living in villages whose farmlands occupied the outlying districts. The inland sections of the North and South were settled by Scots and Scotch-Irish whose traditional pattern of living was to live on their own lands. Thus the growth of cities is among other things a characteristic of the English tradition while rural settlements are a carry-over of the patterns of Scotland and northern Ireland. The cities of the more urban North also grew because of trade and industry.

In building, too, regions of origin in Europe can be traced through the manner in which structures were built. Regionalism and vernacular architecture, however, generally refer to the way in which stylistic elements were treated. Taste was the ruler

by which much of the architecture of Europe and America was measured. The knowledge of the latest trends in taste was generally the responsibility of the patron and not the builder. A basic idea of the requirements of the design and the manner in which it was to be executed was all that was given the craftsman. Perhaps a sketch or a copy of a book or style was given to the builder to translate into a final form. But the technique of erecting the structure was often left to the ingenuity of the builder. How he made the details of the design was left to his own artistic abilities and his knowledge of building traditions.

A study of buildings of various periods indicate that, though the finished appearance of structures differed over a period of time, the way in which the technology changed was a slower process. Buildings in New England dating to the seventeenth century are sometimes very similar to those built during the mid-nineteenth century, despite the fact that the exterior appearance is quite different. Details that are traceable to illustrations in builders' manuals are often widely varied according to the familiarity of the craftsman with stylistic trends, and intermixing of periods often results in the final design.

Like language which is strongly rooted to isolated localities, regionalism and vernacular architecture is a visible indication of the education, interrelation, and sophistication of the craftsmen of an area. And like language, the identification of these differences is an important clue to the understanding of culture and society at a given period of time.

Technical Training of Builders

Until the twentieth century the training process for the building trades was through apprenticeship in guilds. The strength of guilds was that traditions were maintained and new developments were carefully tested before being generally accepted. Apprentices in the building trades became journeymen carpenters and took on apprentices of their own. The underlying order of the trades was conservatism, and the rules of the guilds were the standards by which the tradesmen worked. As late as 1786 in Philadelphia, the Carpenters' Company issued a book of rules intended not only

to regulate the charges for certain work but also to illustrate accepted methods of construction.

The rise of training schools for the building profession did not come about until the last quarter of the nineteenth century. Until that time education remained with the guild apprentice system. With rising demand for mass-produced housing, however, trade schools themselves became a regional characteristic. No longer was individual talent a requirement of the builder; knowledge of the cheapest and quickest way to fabricate a dwelling as well as an absolute familiarity with local building codes became the accepted rule.

The Architect

The architect has perhaps come a longer way in the history of building than any other individual in the field. Originally the chief builder (archi + tect = master builder), he has risen in rank to become the overall designer and exponent of taste in the building profession.

Until the nineteenth century architects were often gentlemen who demonstrated a particular ability to translate building technology into something of beauty. Not all building was architecture, and the talent for turning a building into a thing of beauty required a special touch.

The initial training schools for architects were outgrowths of schools of painting and sculpture. One of the first of these was in Florence, Italy, in the sixteenth century; but the school that most influenced the development of architecture as a profession was the Ecole des Beaux Arts in Paris, founded in 1671. It was not until 1866 that an American school offering independent courses in architecture was founded at the Massachusetts Institute of Technology. Both Robert Mills and Peter Harrison are credited with being the first professionally trained architects in America (contrasted with individuals like Thomas Jefferson who was mostly self-taught), but their training was from abroad and so too were the fashions in buildings. It was not until the rise of independent architects rooted to the regional characteristics of their own homes and determined to develop a truly "American" style of architecture that the European influence of the Ecole began to fade. And on the heels of the new departure came another wave

of European style in the guise of Internationalism.

Although trends in architectural design may waver, the basic traditions of building technology remain steady. Unlike the architect who has chosen to ignore his heritage from the past, the craftsman of today should strive to understand and appreciate this continuity. John Ruskin wrote in his book, **The Stones of Venice** (1851):

> We take pleasure, or **should** take pleasure, in architectural construction altogether as the manifestation of an admirable human intelligence; it is not the strength, not the size, not the finish of the work which we are to venerate: rocks are always stronger, mountains always larger, all natural objects more finished; but it is the intelligence and resolution of man in overcoming physical difficulty which are to be the source of our pleasure and subject of our praise.

Thus even without the fine woods and locally cut heavy timbers of yesterday, today's builder still ought to take pride in a well-done house however modest it may be and whether it is new construction or rehabilitation. Shelter, an eternal and basic need of mankind, may provide both the latest convenience and a link with a common human heritage of technical advance.

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